ORNL/CON-467

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METAEVALUATION OF NATIONAL WEATHERIZATION ASSISTANCE PROGRAM BASED ON STATE STUDIES, 1996–1998

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LOCKHEED MARTIN ENERGY RESEARCH CORPORATION
FOR THE UNITED STATES
DEPARTMENT OF ENERGY

ORNL-27 (3-96)

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May 1999

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LOCKHEED MARTIN ENERGY RESEARCH CORP.
for the
U.S. DEPARTMENT OF ENERGY
under contract number DE-AC05-96OR22464

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ACKNOWLEDGMENTS

We wish to thank those staff members at the state weatherization offices who provided the information that we used in our study of the Weatherization Assistance Program. Without their kind assistance, this report would have not been possible. Similarly, we were assisted by several evaluation contractors, whom we also would like to thank.

Joel Eisenberg and Bruce Tonn, colleagues at Oak Ridge National Laboratory, reviewed a draft of this report and provided valuable comments which led to an improved document.

Finally, we would like to thank Mariann Huskey for the final preparation of this report.

EXECUTIVE SUMMARY

INTRODUCTION

The national Weatherization Assistance Program, sponsored by the U.S. Department of Energy (DOE) and implemented by state and local agencies throughout the United States, weatherizes homes for low-income residents in order to increase their energy efficiency and lower utility bills. Staff at Oak Ridge National Laboratory (ORNL) performed a metaevaluation of this program, which involved synthesizing the results from ten individual studies of state weatherization efforts completed between April 1996 and September 1998. The states whose studies were used in this metaevaluation, the dates of program operations covered by these studies, and the fuels that were examined are shown in Table ES-1. This effort represents a follow-up to an earlier ORNL metaevaluation of the Weatherization Assistance Program that looked at 19 state studies completed between 1990 and early 1996 (Berry 1997). That study, in turn, was done as an update to a national evaluation of the Weatherization Assistance Program that examined a representative sample of several thousand structures weatherized in 1989 (Brown, Berry, Balzer, and Faby 1993).

Table ES-1. Studies used in metaevaluation

		Fuel studied*		
State	Years covered	Natural gas	Electricity (space-heating)	Electricity (non-heating)
Colorado	1995–1996	X		X
Delaware	1995		X	
District of Columbia	1995	X	X	
Indiana	1993–1994	X		
Iowa	1996	X		X
Iowa	1997	X		X
Minnesota	1995–1996	X		
Minnesota	1996–1997	X		
Ohio	1994	X	X	
Vermont	1995–1996	X		X

*While additional fuels (e.g., propane, fuel oil) were covered in a few of the state studies, this evaluation focuses on natural gas and electricity because they were by far the most commonly used.

METHODS

State weatherization staff were contacted to determine which states had evaluated their programs since 1996, and key data required for this metaevaluation were obtained by reading state reports documenting study findings and through follow-up contacts with state-level evaluators. As a result of these efforts, we received usable information on ten recent weatherization program evaluations from seven states and the District of Columbia. Nine of these studies examined houses that used natural gas, three focused on houses with electric heat, and four looked only at the use of electricity for non-heating purposes. Separate analyses were performed for each fuel source and application: one using data from the nine state studies of gas-fueled houses; another using data from the three state studies of electrically-heated dwellings; and a third using the four evaluations of structures that used electricity for nonheating purposes.

The data analyses performed in this metaevaluation had three objectives: (1) to identify average savings experienced by weatherized households in the states that provided information for this evaluation; (2) to identify the key variables that explain the magnitude of weatherization-induced savings reported by the states included in this study; and (3) to estimate average household savings that could be expected nationwide, based on the findings from our set of state studies. The key variable(s) associated with energy savings were identified by running a regression analysis using energy savings as the dependent variable and a number of potentially-related factors as independent variables. The regression analysis was performed only for gas-fueled homes, because this was the only fuel for which there were enough state studies to allow a reasonably accurate analysis. Using the results of this regression analysis, we estimated average household energy savings that could be expected to be achieved nationwide. This was accomplished by taking the regression equation from the model with the best predictive ability and inserting the average national values for the independent variable(s).

KEY FINDINGS

Mean values for pre-weatherization energy consumption, weatherization-induced energy savings, and savings as a percent of pre-weatherization consumption were calculated from the average values reported in the nine state studies of gas-fueled residences. Mean annual pre-weatherization consumption for all end uses was 148.9 million BTUs per household; mean household energy savings amounted to 32.7 million BTUs annually; and mean energy savings equaled 21.0% of pre-weatherization consumption.

A simple regression analysis revealed a strong positive relationship between pre-weatherization energy consumption and weatherization-induced energy savings (R-Square = 0.657; p=.008). This means that, consistent with findings from previous studies, households with higher pre-weatherization energy use tend to save more energy. The R-Square of 0.657 means that 65.7% of the variance in energy savings is explained by pre-weatherization energy consumption.

According to the descriptive equation produced by the simple regression analysis mentioned above, natural gas savings equal −29.06 plus the product of pre-weatherization consumption times 0.415. By inserting the national average of pre-weatherization household natural gas consumption into the equation, we can estimate average national savings. According to the latest national weatherization program evaluation (Brown, Berry, Balzer, and Faby 1993), average pre-weatherization natural gas consumption for all end uses is 133 million BTUs per house, so our estimate of national household savings is 26.1 million BTUs annually. This amounts to 19.6% of average pre-weatherization consumption for all end uses.

Cost-effectiveness was calculated for the weatherization program nationwide. As in past evaluations, we used three different perspectives: the program perspective, which compares the discounted value of energy savings to *total* program costs; the installation perspective, which compares the discounted value of energy savings to labor and material costs; and the societal perspective, which compares the discounted value of both energy and non-energy benefits to total program costs. The benefit/cost ratios that we calculated were 1.51 from the program perspective; 2.02 from the installation perspective, and 2.12 from the societal perspective.

The average savings for gas-fueled households nationwide as calculated in this metaevaluation can be compared to the findings from the previous ORNL metaevaluation and the national evaluation of the 1989 weatherization program. As shown in Table ES-2, average national savings for gas-fueled households as a percent of pre-weatherization consumption for all end uses averaged 19.6% in the time period examined in the latest metaevaluation, 23.4% in the years covered by the previous metaevaluation, and 13.0% in 1989. Although most of the state studies did not measure the portion of total pre-weatherization consumption that went for space-heating, this can be estimated to allow comparison with previous studies. We found that, nationwide, household natural gas savings as a percent of pre-weatherization consumption for space-heating averaged 27.6% in the years covered by the current metaevaluation, 33.5% in the period examined in the previous ORNL metaevaluation, and 18.3% in 1989.

Table ES-2. Estimated nationwide savings from this metaevaluation and previous studies

	Average household natural gas savings, in MBTU (followed by 90% confidence interval)	Average household natural gas savings as a percent of pre-weatherization consumption for all end uses, in % (followed by 90% confidence interval)	Average household natural gas savings as a percent of pre-weatherization consumption for space-heating, in % (followed by 90% confidence interval)
Current ORNL metaevaluation: 1996–1998 studies	26.1 (19.4–32.8)	19.6 (14.6–24.6)	27.6 (20.5–34.7)
Previous ORNL metaevaluation: 1990–1996 studies	31.2 (22.9–38.6)	23.4 (17.2–29.0)	33.5 (24.6–41.4)
1989 national evaluation	17.3 (15.1–19.5)	13.0 (11.3–14.7)	18.3 (16.0–20.6)

A look at the 90% confidence intervals presented in Table ES-2 indicates that there is no significant difference between the average savings estimated by the two metaevaluations, because there is substantial overlap in their ranges of possible nationwide savings. In contrast, the 90% confidence interval for national savings from the 1989 national evaluation has no overlap with the confidence interval from the first metaevaluation and only an extremely small overlap with the confidence interval from the current metaevaluation. The implication of this finding is that weatherization-induced savings have, in fact, increased significantly since 1989. Accordingly, benefit/cost ratios have increased as well.

There are several possible reasons why weatherization-induced energy savings increased between 1989, the year studied in the national weatherization evaluation, and 1996, when the first metaevaluation was conducted. Advanced audits became widely used; the use of blower-doors as a diagnostic tool became commonplace; and cooling efficiency measures became allowable due to changes in DOE regulations. Since 1996, however, there have been no equally dramatic changes in the structure or practices of the Weatherization Assistance Program, and this accounts for the fact that there has been no significant change in the magnitude of energy savings between the previous metaevaluation and this one.

1. INTRODUCTION

1.1 BACKGROUND

Under the sponsorship of the U.S. Department of Energy (DOE), the national Weatherization Assistance Program has weatherized more than four million low-income residences since its inception in 1976. This federally funded program, which is implemented by state and local agencies in all 50 states and the District of Columbia, is designed to increase residential energy efficiency, thereby lowering energy costs for low income occupants and improving their health and comfort.

This report documents the findings of a recent metaevaluation of the Weatherization Assistance Program conducted by staff at Oak Ridge National Laboratory (ORNL). A metaevaluation is a study that uses as its data points the findings from a number of individual studies on the topic of interest. In this case, the performance of the national Weatherization Assistance Program is the focus, and the data points are the findings from ten evaluations of individual states' weatherization efforts completed between April 1996 and September 1998. The states whose studies were used in this metaevaluation are shown in Figure 1.

The study that is the focus of this report is a follow-up to a metaevaluation of the Weatherization Assistance Program performed by ORNL in 1996 (Berry 1997). That study, in turn, was performed in order to update the findings from a national evaluation of the Weatherization Assistance Program that ORNL conducted in the early 1990s (Brown, Berry, Balzer, and Faby 1993). The national evaluation examined a representative sample of several thousand structures weatherized in 1989, while the 1996 metaevaluation looked at 19 state studies that were completed between 1990 and early 1996.

The metaevaluation performed by ORNL in 1996 found substantially greater energy savings in the time period 1990–1996 than were realized by the Weatherization Assistance Program in 1989. There are several possible reasons for this, most notably: (1) advanced audits, which were not available in 1989, were widely used by the mid-1990s; (2) the use of blower-doors to guide efforts to reduce air infiltration became much more common after 1990 than had previously been the case; and (3) new DOE regulations permit the use of cooling efficiency measures that were previously not included in low-income weatherization efforts.

Between the completion of the 1996 metaevaluation and the current study, no dramatic changes were made in the structure or practices of the Weatherization Assistance Program. Accordingly, the authors began this project with the expectation that the magnitude of energy savings revealed by this study would be similar to what was found in the previous metaevaluation. This, in fact, proved to be the case.

1.2 SCOPE OF REPORT

The subsequent chapters of this report describe the research methods used in this metaevaluation and discuss the key findings. Chapter 2 provides information on the state studies that were examined and how the data provided by these individual studies were analyzed. Chapter 3 presents energy and dollar savings for buildings heated with natural gas, examines key

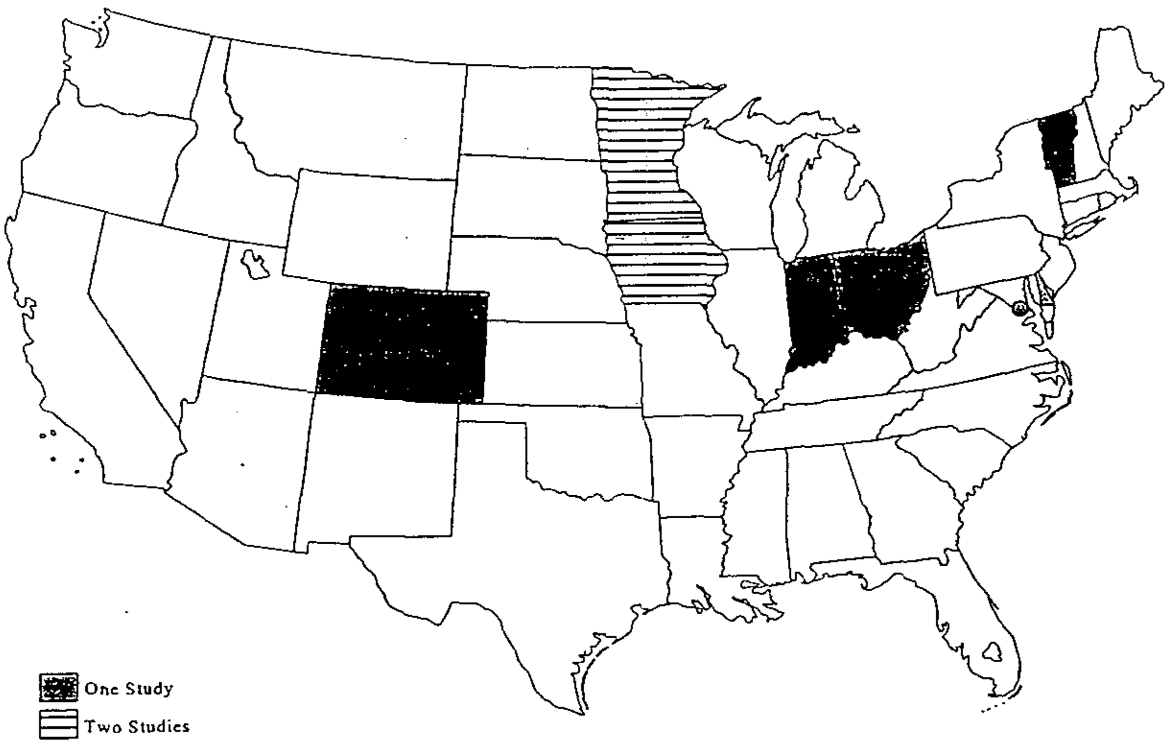

Figure 1. States with weatherization program studies used in metaevaluation.

factors that could possibly explain the findings, and gives an estimate of average household savings nationwide. Findings are not presented in the body of this report regarding electricity use because the number of states that studied this fuel is too small to allow reliable analytical results; however a brief discussion of electricity savings is presented in Appendix B. In Chapter 4, the findings from this study are compared to those from the previous metaevaluation and the earlier national evaluation of the Weatherization Assistance Program.

2. METHODS

2.1 SELECTING STATE EVALUATIONS

The first step in conducting the 1998 metaevaluation was to identify all states that had evaluated their weatherization programs since 1996, when the previous ORNL metaevaluation was performed. We already knew the status of evaluation efforts in four states[1] that had been working closely with ORNL to design and implement weatherization program evaluations. For the other 46 states and the District of Columbia, we elicited the needed information by sending a letter to their weatherization staff asking for a description of any evaluations that had been completed or documented in their jurisdiction since April 1996. These letters also asked for the name of an individual who could be contacted for more information and requested some information on each state's data system for keeping track of weatherization activities and on the weatherization measure selection techniques currently in use. The key information received from each state as a result of these contacts is presented in Appendix A.

After state weatherization staff responded to the information request letter described above, we made telephone calls to the appropriate contact person in each state where an evaluation had been completed since April 1996 and requested a copy of the report documenting their study. The reports that we received are cited in the References section. We also designed a data collection form indicating every variable that would be needed to perform a metaevaluation. After reading each report, we filled in a data collection form to the extent possible and made follow-up calls to the state weatherization contact to request any missing information. In those two cases where an evaluation had been performed but a report had not been written,[2] we sent a data collection form to the state contact and asked that individual to complete it.

As shown in Table 1, we received usable information[3] on ten recent weatherization program evaluations in seven states and the District of Columbia. Colorado, Delaware, Indiana, Ohio, Vermont, and Washington, D.C., each provided results from a single evaluation, while Iowa and Minnesota had conducted two separate evaluations apiece during the study period. Although we requested information only on those evaluations that had been completed or documented since April 1996, much of the data that we received covered program years prior to 1996 because of the substantial amount of time required to collect and analyze energy consumption data and prepare reports documenting study findings.

Most of the state studies used in this metaevaluation examined the use of natural gas, electricity, or both. Only a couple of evaluations included information on other fuels, such as propane or fuel oil, and they are too few to warrant discussion in this report. Nine of the ten state

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[1]The four states with which ORNL had already been working on weatherization program evaluations are California, Georgia, Texas, and Washington.

[2]Reports were not available for the evaluations of Indiana's 1993–1994 weatherization program and Minnesota's 1996–1997 program.

[3]To be usable, an evaluation had to identify the weatherization-induced energy savings that would occur in a year with typical weather, often referred to as "weather-normalized annual savings."

Table 1. Key features of state evaluations

State	Program year	Control group	Method of calculating energy savings	Fuel studied*	Number of weatherized buildings
Colorado	1995–1996	Yes	Regression analysis	Natural gas Electricity	2,442 1,937
Delaware	1995	Yes	PRISM	Electricity	25
District of Columbia	1995	No	Site-specific weather-sensitivity coefficients used to normalize energy consumption	Natural gas Electricity	159 10
Indiana	1993–1994	No	PRISM	Natural gas	49
Iowa	1996	No	Adjustment factors applied to tracking data base	Natural gas Electricity	1,074 829
Iowa	1997	No	Adjustment factors applied to tracking data base	Natural gas Electricity	1,877 2,229
Minnesota	1995–1996	No	Data loggers/ASAP (with DESLog software)	Natural gas	32
Minnesota	1996–1997	No	Data loggers/ASAP (with DESLog software)	Natural gas	44
Ohio	1994	Yes	PRISM	Natural gas Electricity	2,209 154
Vermont	1995–1996	No	PRISM	Natural gas Electricity	35 82

*A few state studies included information on additional fuels (e.g., propane, fuel oil), but this study focuses only on natural gas and electricity.

studies examined houses that used natural gas and seven looked at houses that used electricity (Table 1). Three of the studies of electricity use focused on houses with electric heat and four looked only at the use of electricity for nonheating purposes. The number of houses examined varied widely from study to study. For studies of natural gas consumption, four were based on data for less than 100 houses while another four looked at over 1,000 houses. On the electricity side, three of the studies examined less than 100 houses and two evaluated savings for over 1,000 structures.

A variety of methods was used to calculate energy savings, as shown in Table 1. In the majority of cases, savings were identified by tracking monthly energy bills for a period of approximately 12 months both before and after weatherization. These billing records were most often analyzed with a software system called PRISM, which stands for PRInceton Scorekeeping Method (Fels, Kissock, Marean, and Reynolds 1995; Fels and Reynolds 1990). In two studies, data loggers were attached to heating systems to directly measure pre- and post-weatherization energy consumption with the Achieved Savings Assessment Program (ASAP) which uses DESLog software to do weather-normalization and calculate energy savings (Minnesota Office of Low-income Energy Programs 1998) and, in another two cases, savings were calculated by applying empirically-derived adjustment factors to engineering estimates of savings associated with the weatherization measures that were installed in the households under study. Of the ten state studies used for this metaevaluation, three used control groups and seven did not. Any changes in household energy use experienced during the study period by the control group—which is a set of unweatherized houses—represents change that is likely to have occurred in the treated houses in the absence of weatherization. Accordingly, the analyst can subtract these changes from those observed in the weatherized structures to get adjusted savings (often referred to as net savings), which are generally considered to be more accurate than unadjusted (gross) savings.

2.2 WORKING WITH THE DATA

The purpose of the data analysis performed in this metaevaluation was threefold: (1) to identify average savings experienced by weatherized households in the states that provided information for this evaluation; (2) to identify the key variables that explain the magnitude of weatherization-induced savings reported by the states included in this study; and (3) to estimate average household savings that could be expected nationwide, based on the findings from our set of state studies.

In a metaevaluation, the average value for any given variable from one study constitutes a single data point. So, for example, the portion of this metaevaluation that examines gas-fueled households has nine data points for pre-weatherization energy consumption, with each one consisting of the average consumption calculated from all houses examined in one of the state studies. No variable in this metaevaluation could have more than nine data points, because there are only nine state studies of gas-fueled dwellings in our data set. However, it is possible for there to be less than nine data points for a given variable because one or more studies might not have provided usable data for a particular item.

The major *outcome* of interest in this metaevaluation is the magnitude of energy savings experienced by weatherized households. Our data points for this variable are the average annual energy savings identified in each of the state studies described in Section 2.1. Most of the state studies did not employ a control group, so the energy savings they identified are gross (or unadjusted) savings. However, a few states reported net savings that had been adjusted based on the performance of a control group, and we used these adjusted savings whenever they were available. Average savings for the entire set of state studies was calculated by taking the arithmetic mean of the average savings reported in the individual studies, and the 90% confidence interval also was computed.[4] Separate calculations were made for different fuel sources and applications: one using data from the nine state studies of gas-fueled houses; another using data from the three state studies of electrically-heated dwellings; and a third using the four evaluations of structures that used electricity for nonheating purposes. The findings for the gas-fueled homes are presented in Chapter 3, while electricity savings (which are based on a smaller number of observations) are discussed in Appendix B.

The key variable(s) that are associated with the magnitude of weatherization-induced energy savings were identified by running a regression analysis using energy savings as the dependent variable and a number of factors that could potentially explain energy savings as independent variables. These potential explanatory variables are: (1) pre-weatherization energy consumption; (2) square footage of the weatherized structures; (3) heating degree days in the project area; and (4) weatherization expenditures. They were selected because they had been shown to be significantly related to energy savings in the national weatherization program evaluation (Brown, Berry, Balzer, and Faby 1993), the previous metaevaluation (Berry 1997), or both, and because data on these factors were provided by the state studies or could be easily estimated or obtained from another source. The regression analysis was performed only for gas-fueled homes, because this was the only fuel for which there were enough state studies (nine) to allow a reasonably accurate analysis. The samples for electrically-heated houses (three studies) and houses using electricity for non-heating purposes (four studies) were too small to produce meaningful results. More information about the independent variables used in the regression analysis of gas-fueled residences is provided in Appendix C.

Using the results of the regression analysis performed for the gas-fueled houses, we were able to estimate average household energy savings that could be expected to be achieved nationwide. This was done by taking the regression equation from the model with the best predictive ability and inserting the average national values for the independent variable(s). This process is explained more fully in Chapter 3.

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[4]Confidence intervals, which were calculated for pre-weatherization consumption and energy savings, tell us the range within which the value of a given variable is likely to fall for an entire population, at a given level of certainty (e.g., 90%).

3. FINDINGS

3.1 NATURAL GAS SAVINGS FROM STATE STUDIES

Mean values for pre-weatherization energy consumption, weatherization-induced energy savings, and savings as a percent of pre-weatherization consumption were calculated from the average values reported in the nine state studies of gas-fueled residences. Mean annual pre-weatherization consumption for all end uses was 148.9 million BTUs per household; mean household energy savings amounted to 32.7 million BTUs annually; and mean energy savings equaled 21.0% of pre-weatherization consumption.[5] These values, plus the minimum and maximum and 90% confidence interval for each variable are shown in Table 2.

Table 2. Key findings from nine state weatherization program studies of gas-heated structures

	Minimum	Maximum	Mean	90% confidence interval
Pre-weatherization consumption for all end uses (MBTU)	102.3	190.2	148.9	131.2–166.6
Absolute savings* (MBTU)	11.0	60.5	32.7	23.7–41.8
Savings as a percent of pre-weatherization consumption (%)	8.5	29.8	21.0	17.1–24.9

*These numbers are calculated from net savings in those cases where a control group was used and gross savings in all other cases.

3.2 EXPLAINING NATURAL GAS SAVINGS

Several different regression analyses were run to examine possible relationships between natural gas savings and four potential explanatory variables: pre-weatherization consumption; square footage of structure; heating degree days; and weatherization expenditures. A simple regression analysis was performed using energy savings as the dependent variable and pre-weatherization consumption as the sole independent variable. Subsequent analyses used each of the other possible explanatory factors listed above as the sole independent variable in order to determine its relationship to energy savings. An additional simple regression analysis tested the possible relationship between one of the independent variables (heating degree days) and energy

[5]The mean value given here for energy savings as a percent of pre-weatherization consumption was calculated from the values for this variable reported by all the individual state studies. If this value were calculated from the nine-study average values for energy savings and pre-weatherization consumption, the result would be slightly different.

savings for a data set that excluded one of the state studies that had some atypical—and potentially confounding—values for the variables involved.[6] The results of these simple regression analyses are shown in Table 3.

Table 3. Results of simple regression analyses testing relationship between possible explanatory variables and natural gas savings

Explanatory variable	N	F-value	p-value	R-square
Pre-weatherization consumption for all end uses	9	13.40	.008	0.657
Square footage of structure	9	1.54	.25	0.181
Heating degree days	9	0.30	.60	0.041
Heating degree days for reduced data set	8	6.57	.04	0.523
Weatherization expenditures	6	0.17	.70	0.041

Like previous studies (e.g., Columbia Gas of Ohio 1995, Berry 1997), this metaevaluation found a strong positive relationship between pre-weatherization energy consumption and weatherization-induced energy savings (R-Square=0.657; p=.008). In other words, households with higher pre-weatherization energy use tend to save more energy (Figure 2). The R-Square of 0.657 means that 65.7% of the variance in energy savings is explained by pre-weatherization energy consumption, and the p-value of .008 means that there is a probability of only eight in a thousand that the observed relationship could have occurred by chance. The only other independent variable that was found to be significantly related to energy savings was heating degree days for the reduced data set that excluded one study focusing on households with abnormally high values for pre-weatherization consumption. For the reduced data set, energy savings and heating degree days were found to be positively related (p=.04; R-Square=0.523), although the relationship was not as strong as the one between pre-weatherization consumption and energy savings. Because heating degree days and pre-weatherization consumption tend to be positively related (i.e., houses in colder climates use more energy) and pre-weatherization consumption is strongly associated with energy savings, the finding that homes in colder climates tend to achieve greater savings is not surprising.

Following the series of simple regression analyses described above, we ran a multiple regression analysis to test the relationship between energy savings and all four independent variables in the presence of each other. We also ran multiple regression analyses using various

[6] One of the state studies focused on households that had especially high pre-weatherization energy consumption, despite their location in a relatively mild climate. The positive relationship between heating degree days and pre-weatherization consumption found in many other studies (i.e., as one goes up the other does too) did not apply here. Because pre-weatherization energy consumption typically is strongly related to energy savings, the inclusion of this study in the sample masked the relationship between heating degree days and energy savings.

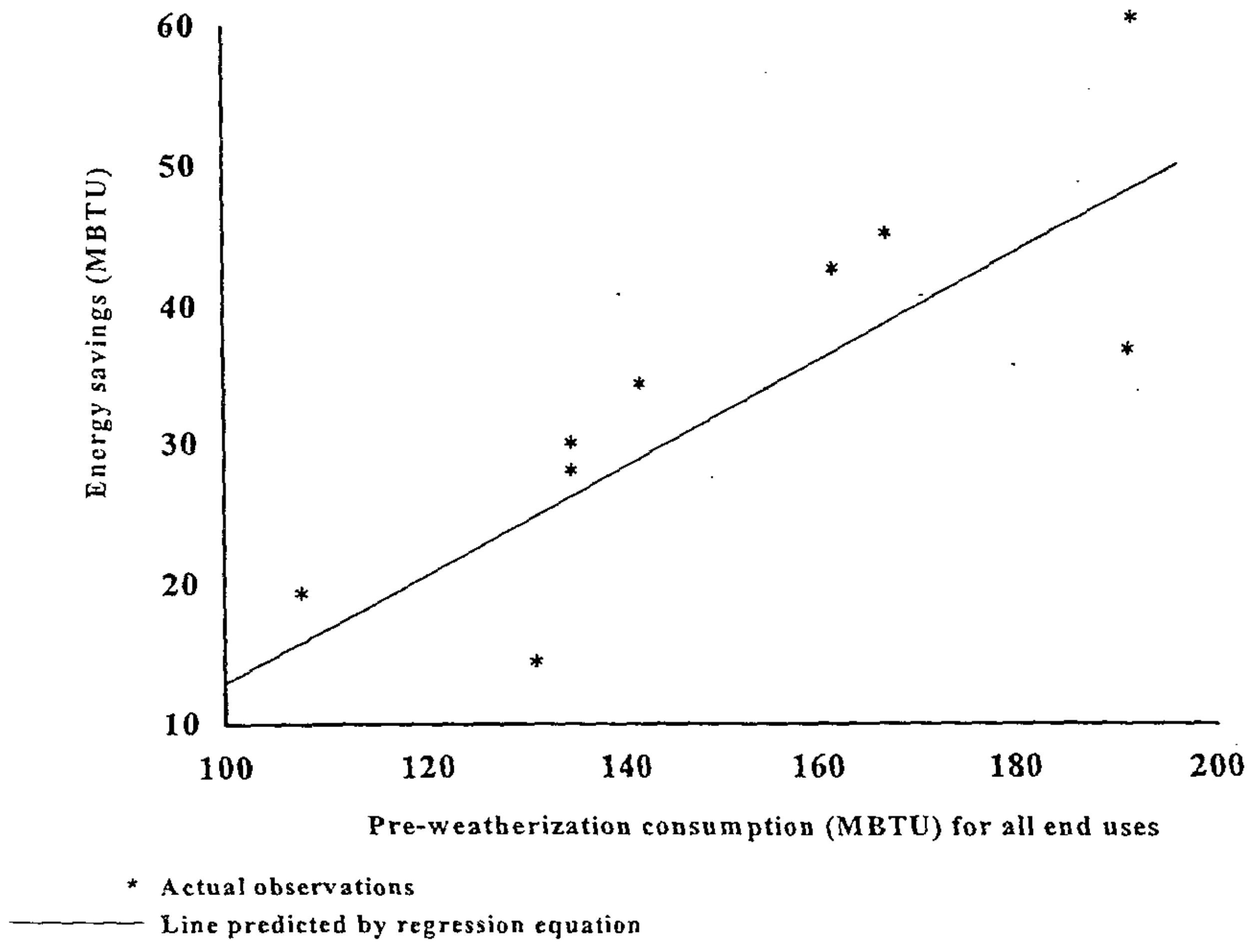

Figure 2. Plot of energy savings by pre-weatherization consumption for gas-heated structures.

subsets of the four independent variables. The result was that none of the multiple regression models yielded statistically significant results with greater explanatory power than the one-variable model using pre-weatherization energy consumption as the sole independent variable.

3.3 ESTIMATE OF AVERAGE NATIONAL SAVINGS FOR BUILDINGS HEATED WITH NATURAL GAS

As shown in Table 4, the one variable regression model that describes household natural gas savings in terms of its relationship with pre-weatherization energy consumption can be used to predict annual average savings nationwide. The descriptive equation produced by our simple regression analysis is that natural gas savings equal −29.06 plus the product of

Table 4. Estimate of average national savings using pre-weatherization consumption as predictive variable

One-variable regression equation [$R^2 = 0.657$; $p = .008$]:

Annual natural gas savings = −29.06 + (0.415 × pre-weatherization consumption)

National average of pre-weatherization household natural gas consumption for all end uses:

133 MBTU*

Predicted average household natural gas savings, nationwide:

−29.06 MBTU + (0.415 × 133 MBTU) = 26.1 MBTU
90% confidence interval: 19.4–32.8 MBTU (26.1 ± 6.7)

Predicted average household savings as a percent of pre-weatherization consumption for all end uses:

26.1 MBTU / 133MBTU = 19.6%
90% confidence interval: 14.6–24.6% (19.6% ± 5.0)

*National average taken from 1989 National Weatherization Evaluation (Brown, Berry, Balzer, and Faby 1993).

pre-weatherization consumption times 0.415.[7] By inserting the national average of pre-weatherization household natural gas consumption into the equation, we can estimate average national savings for dwellings using natural gas. According to the latest national weatherization program evaluation (Brown, Berry, Balzer, and Faby 1993), average pre-weatherization natural gas consumption for all end uses is 133 million BTUs per house, so our estimate of national household savings is 26.1 million BTUs annually. This amounts to 19.6% of average pre-weatherization consumption for all end uses. The 90% confidence intervals for estimated average

[7]Although our study used MBTUs (million BTUs) as the unit of measure, this equation would apply to any energy unit (e.g., therms, ccf), used to measure natural gas consumption.

household energy savings and for average savings as a percent of pre-weatherization consumption are included in Table 4.

3.4 COST EFFECTIVENESS RESULTS FOR BUILDINGS HEATED WITH NATURAL GAS

Cost effectiveness was calculated for the weatherization program nationwide. Average annual energy savings per household (calculated in Sect. 3.3) was multiplied by average gas prices to get average annual dollar savings. Program costs were taken from the national weatherization program evaluation and adjusted for inflation.

As in past evaluations of the weatherization program, we used three perspectives for estimating cost effectiveness: the program perspective, the installation perspective, and the societal perspective. The program perspective compares the discounted value of energy savings to total program costs (including labor, materials, overhead, administrative and all other categories of fixed or variable costs). The installation perspective compares the discounted value of energy savings to installation-related costs (labor and materials). The societal perspective compares the discounted value of both energy and non-energy benefits[8] to total program costs.

To make the current benefit/cost ratios comparable to those from the previous metaevaluation and the national evaluation of the 1989 program, the same assumptions and procedures were used. In particular, the average measure lifetime was assumed to be 20 years and the discount rate used was 4.7%. Following the findings of the national evaluation, the net present value of non-energy benefits was assumed to be $976.

With the program perspective, the benefit/cost ratio for the current metaevaluation was 1.51, meaning that $1.51 of benefits were received for every $1 spent. Under the installation perspective, the benefit/cost ratio was substantially higher, at 2.02. With the societal perspective, which includes the value of non-energy benefits as well as all costs, the ratio was 2.12.

[8]The types of non-energy benefits considered in this analysis include affordable housing, comfort, health and safety, reduced utility arrearages and terminations, employment and economic benefits, and environmental externalities of the Weatherization Assistance Program.

4. Conclusions

Based on average savings reported in nine state-level studies of the weatherization of gas-fueled houses completed between 1996 and 1998, this metaevaluation found mean energy savings amounting to 21% of pre-weatherization consumption for all end uses. This is very close to the savings of 22% reported in the previous ORNL metaevaluation, which examined 17 studies of state weatherization programs conducted between 1990 and 1996 (Berry 1997).

Both metaevaluations went on to estimate average household savings *nationwide*, using the best regression model developed in the course of the evaluation and entering average national values for the independent variable(s). These estimates of nationwide savings can be compared to the findings from the national evaluation of the 1989 weatherization program to see how energy savings have changed over time. As shown in Table 5, national savings for gas-fueled households as a percent of pre-weatherization consumption for all end uses averaged 13.0% in 1989, 23.4% in the years covered by the previous metaevaluation, and 19.6% in the time period examined in the latest metaevaluation.

Table 5. Comparison of estimated average national savings from this metaevaluation with findings from past studies

	1989 national evaluation	Previous ORNL metaevaluation (1990–1996 studies)	Current ORNL metaevaluation (1996–1998 studies)
Average household natural gas savings (MBTU)	17.3	31.2	26.1
90% confidence interval:	*15.1–19.5*	*22.9–38.6*	*19.4–32.8*
Average household natural gas savings as a percent of pre-weatherization consumption for all end uses (%)	13.0	23.4	19.6
90% confidence interval:	*11.3–14.7*	*17.2–29.0*	*14.6–24.6*
Average household natural gas savings as a percent of pre-weatherization consumption for spaceheating (%)	18.3	33.5	27.6
90% confidence interval:	*16.0–20.6*	*24.6–41.4*	*20.5–34.7*

Most of the state studies reported pre-weatherization consumption for all end uses and did not measure the portion of this energy use that went for space-heating. However, in order to allow comparison with previous studies, we estimated pre-weatherization space-heating consumption and calculated average household savings as a percent of that.[9] Table 5 shows that, nationwide, household natural gas savings as a percent of pre-weatherization consumption for space-heating averaged 18.3% in 1989, 33.5% in the period examined in the previous ORNL metaevaluation, and 27.6% in the years covered by the latest metaevaluation.

The findings presented in Table 5 clearly show that energy savings have increased since 1989, but the national savings estimated by the latest metaevaluation are slightly less than those estimated in the earlier ORNL study. Does this mean that weatherization-induced savings have actually declined in the last two years?

A look at the 90% confidence intervals presented in Table 5 indicates that there is no significant difference between the average savings estimated by the two metaevaluations, because there is substantial overlap in their ranges of possible nationwide savings. This is illustrated graphically by Figure 3. The current metaevaluation indicates that there is a 90% probability that average household natural gas savings are between 14.6% and 24.6% of pre-weatherization consumption for all end uses, nationwide. The previous metaevaluation estimated that average savings fell somewhere between 17.2% and 29.0 % of pre-weatherization whole-house energy use. In contrast, the 90% confidence interval for national savings from the 1989 national evaluation has no overlap with the confidence interval from the first metaevaluation and only an extremely small overlap with the confidence interval from the current metaevaluation. The implication of this finding is that weatherization-induced savings have, in fact, increased significantly since 1989.

Because of the higher average national energy savings estimated by both ORNL metaevaluations, the benefit/cost ratios for these years also were higher than the ones reported by the national evaluation for the 1989 program year (Table 6).

As noted in Chapter 1, there are several possible reasons why weatherization-induced energy savings increased between 1989 and 1996, when the first metaevaluation was conducted. Advanced audits, which allow the identification and installation of more effective energy-saving measures, became widely used. Similarly, the use of blower-doors, which lead to greater reduction of air infiltration in weatherized houses, became commonplace.

Finally, cooling efficiency measures that were previously not included in the package of weatherization measures became allowable due to changes in DOE regulations. Since 1996, however, there have been no equally dramatic changes in the structure or practices of the Weatherization Assistance Program, and this accounts for the fact that the magnitude of energy savings has not changed significantly from the previous metaevaluation to this one.

Future evaluations can document the effects of any changes that are made in the way the Weatherization Assistance Program is structured and implemented. Within a given state, the effects of any new practice can be observed by comparing energy savings in the houses utilizing the new approach with savings in those houses served in the traditional manner. This applies to

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[9]A 1987 national survey found that, for gas-heated low-income households nationwide, 71% of total gas consumption went for space-heating (Brown, Berry, Balzer, and Faby 1993). The average pre-weatherization natural gas consumption of 133 million BTUs per house reported in the latest national weatherization program evaluation was multiplied by 0.71 to yield an average household pre-weatherization space-heating usage of 94.4 million BTUs.

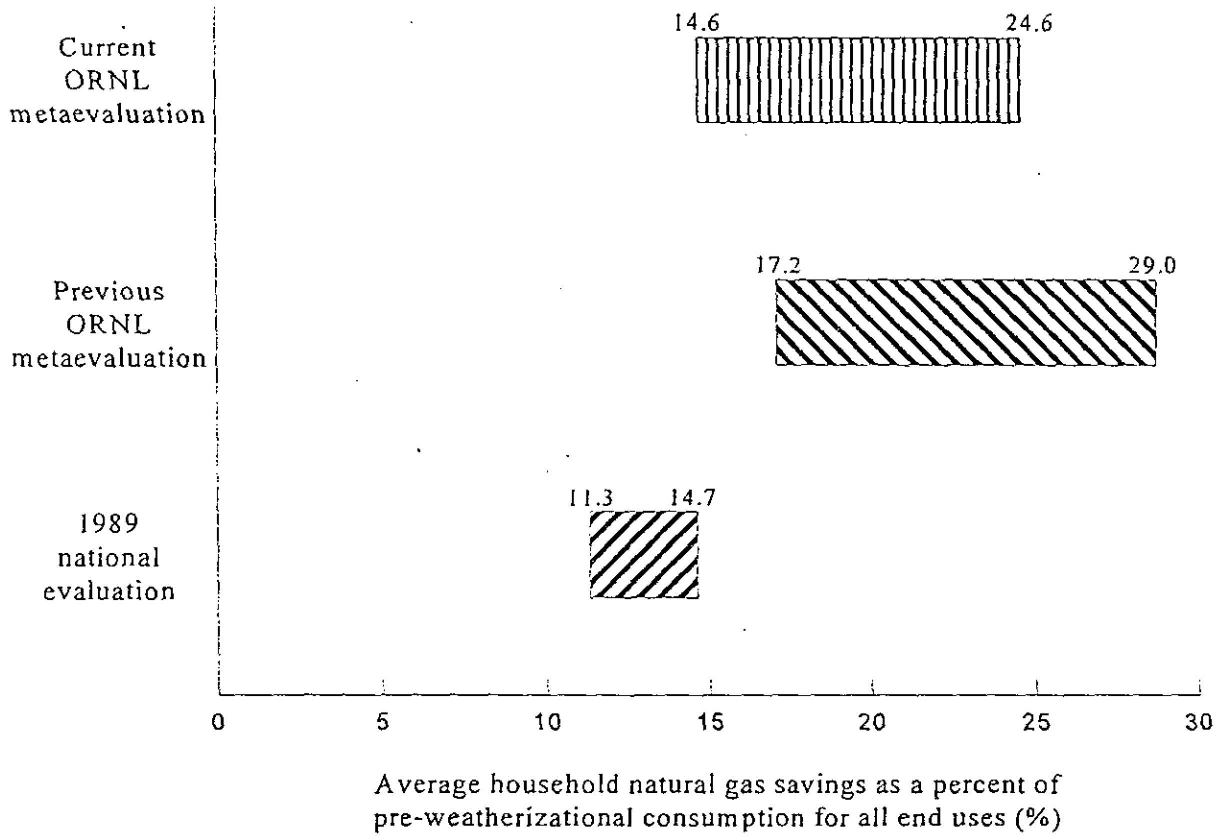

Figure 3. Average national whole-house savings: 90% confidence intervals from three evaluations.

Table 6. Benefit/cost ratios for national evaluation and both metaevaluations

	Program perspective	Installation perspective	Societal perspective
1989 national evaluation	1.06	1.58	1.61
Previous ORNL metaevaluation	1.79	2.39	2.40
Current ORNL metaevaluation	1.51	2.02	2.12

any changes in average expenditures per household that may occur over time as well as to the introduction of any other new procedures. At the meta level, average savings can be compared for states that differ from each other regarding key program characteristics.

This metaevaluation has shown that improvements to the Weatherization Assistance Program made in the first half of this decade continue to be effective and to reap benefits for program participants. Future metaevaluations can assist program administrators and other interested parties by showing the effects of any subsequent changes that are made to the Weatherization Assistance Program.

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APPENDIX A

STATE WEATHERIZATION OFFICE SURVEY RESULTS

Table A.1. State weatherization contacts, measure selection techniques, data systems, and evaluations

State	Initial contact	Other contact recommended for additional information	Technique(s) used to select weatherization measures	Data system(s) that could be used to measure program performance	Evaluation(s) completed or documented between April 1996 and September 1998	Planned evaluation(s) to be completed after September 1998	State evaluation results used in meta evaluation?
Alabama	Ms. Brenda Jones Alabama Dept. of Economic and Community Affairs P.O. Box 5690 Montgomery, AL 36103-5690 Ph: (334) 242-5376 Fax: (334) 242-4203	None	National Energy Audit (NEAT) *and* a priority list	None	None	Measurement of pre- and post-weatherization energy consumption for homes served in 1997	No
Alaska	Mr. Scott Waterman Alaska Housing Finance Corp. P.O. Box 101020 Anchorage, AK 99510-1020 Ph: (907) 330-8195 Fax: (907) 338-1747	None	AKWarm (computerized audit)	None	None	Measurement of pre- and post-weatherization energy consumption and costs: analysis of billing data and oil use data logger	No
Arizona	Mr. Russell Clark Arizona Energy Office 3800 N. Central Phoenix, AZ 85012 Ph: (602) 280-1430 Fax: (602) 280-1445	None	REM Design (audit) *and* priority lists	None	None	Examination of post-weatherization energy consumption	No
Arkansas	Mr. Thomas E. Green Office of Community Services P.O. Box 1437, Slot 1330 Little Rock, AR 72203-1437 Ph: (501) 682-8715 Fax: (501) 682-6736	None	NEAT *and* Manufactured Home Energy Audit (MHEA)	None	None	None	No
California	Ms. Toni Curtis Department of Community Services and Development 700 North 10th St., Room 258 Sacramento, CA 95814 Ph: (916) 322-2940 Fax: (916) 327-3153	Ms. Maria Federer Ph: (916) 322-2458	Priority List from Heath Associates Study	None	None	Analysis of savings from homes weatherized between August 1, 1996, and March 31, 1997 with assistance from ORNL	No
Colorado	Mr. Robert DeSoto Office of Energy Conservation 1675 Broadway, Suite 1300 Denver, CO 80202-4613 Ph: (303) 620-4292 Fax: (303) 620-4288	Mr. Rick Hanger Office of Energy Conservation Ph: (719) 644-0136	The Audit Program (TAP)	No	Analysis of savings from weatherization program for 1995–1996	Analysis of savings from homes weatherized in 1996 and 1997 is expected	Yes

Table A.1. Continued

State	Initial contact	Other contact recommended for additional information	Technique(s) used to select weatherization measures	Data system(s) that could be used to measure program performance	Evaluation(s) completed or documented between April 1996 and September 1998	Planned evaluation(s) to be completed after September 1998	State evaluation results used in meta evaluation?
Connecticut	Ms. Carlene Taylor State Dept. of Social Services 25 Sigourney Street Hartford, CT 06106 Ph: (860) 424-5889 Fax: (860) 424-4952	None	Portable Residential Conservation Service (RCS) Audit/ Conservation Services Group	None	None	None	No
Delaware	Mr. G. Kenneth Davis Office of Community Services Carvel State Office Building 820 N. French Street, 4th Floor Wilmington, DE 19801 Ph: (302) 577-4965, ext. 232 Fax: (302) 577-4973	Dr. John Byrne University of Delaware Ph: (302) 831-8405	NEAT and priority list	None	Evaluation of the impacts of the Delaware low-income weatherization program on energy and economic savings. Completed in December 1996	None	Yes
District of Columbia	Mr. Carl Williams DC Energy Office 2000 14th Street, NW, Suite 300E Washington, DC 20008 Ph: (202) 673-6741 Fax: (202) 673-6725	Mr. Darrell Riddick DC Energy Office Ph: (202) 673-6746	NEAT	None	Multiple regression analysis to determine factors responsible for energy savings	Study of the time involved in weatherizing homes and ways to decrease it	Yes
Florida	Mr. Earl Billings Dept. of Community Affairs 2740 Centerview Drive Tallahassee, FL 32399-2100 Ph: (850) 488-7541 Fax: (850) 488-2488	None	NEAT	None	None	None	No
Georgia	Ms. Cherry Ivy 2090 Equitable Bldg. 100 Peachtree St. NW Atlanta, GA 30303 Ph: (404) 656-3826	None	Priority List	None	None	Analysis of savings from homes weatherized between January 1996 and March 1997 with assistance from ORNL	No
Hawaii	Mr. Bob Hoffman Dept. of Labor and Industrial Relations 335 Merchant Street, Room 101 Honolulu, HI 96813 Ph: (808) 586-8675 Fax: (808) 586-8685	Mr. Dennis Doi Office of Community Services Ph: (808) 586-8675	Walk-through Audit	None	None	None	No

Table A.1. Continued

State	Initial contact	Other contact recommended for additional information	Technique(s) used to select weatherization measures	Data system(s) that could be used to measure program performance	Evaluation(s) completed or documented between April 1996 and September 1998	Planned evaluation(s) to be completed after September 1998	State evaluation results used in meta evaluation?
Idaho	Ms. Neva Kaufman State Economic Opportunity Office 450 W. State Street State House Mail Boise, ID 83720-9990 Ph: (208) 334-5732 Fax: (208) 332-7343	Ms. Robyn Carlson Dept. of Health and Welfare Ph: (208) 334-5736	EA3 (spreadsheet)	None	Comparison of actual labor and support costs incurred during home weatherizations with numbers predicted by audit	Evaluation of potential cost savings from central bidding process and effects of changes in cost estimation procedures	No, because evaluation did not examine energy or cost savings
Illinois	Mr. Wayne E. Curtis IL Dept. of Commerce and Community Affairs 620 E. Adams St., 4th Floor Springfield, IL 62701 Ph: (217) 524-8024 Fax: (217) 782-1206	Mr. Edward Haber Dept. of Commerce and Community Affairs Ph: (217) 524-8032	Wisconsin Home Energy Audit (WHEA)	Reporting on measures completed	None	In process of developing an ongoing evaluation system	No
Indiana	Mr. Ed Gerardot Indiana CAP Directors' Association 902 N. Capitol Avenue Indianapolis, IN 46204 Ph: (317) 638-4232 Fax: (317) 634-7947	Dr. Bill Hill Ball State University Ph: (765) 285-8144	Priority list *and* NEAT, REM Design/ REM Rate	Sub-grantees collect pre- and post-weatherization data for some houses	Identified costs, benefits, and energy savings from weatherization pilot project with utility	May do analysis of pre- and post-weatherization energy use, based on billing data collected by subgrantees. May also do metered evaluation for bulk fuel client.	Yes
Iowa	Mr. Gregory K. Dalhoff Dalhoff and Associates 533 Marshall Circle Verona, WI 53593 Ph: (608) 845-6551 Fax: (608) 845-6544	None	NEAT	State's consultant is considering developing an integrated tool to allow routine assessment of performance	Report on impacts and costs of the state's 1996 and 1997 low-income weatherization programs	An assessment of the weatherization program's impacts on arrearages may be done in the future	Yes
Kansas	Ms. Norma Phillips Dept. of Commerce and Housing 700 S.W. Harrison Street, Suite 1300 Topeka, KS 66660-3755 Ph: (913) 296-2686 Fax: (913) 296-8985	Mr. Douglas Walter Kansas Bldg. Science Institute Ph: (785) 537-2425	NEAT *and* profiles of typical dwelling units based on a sample of 800 units	PRISM	None	Annual evaluations of energy savings	No
Kentucky	Mr. Pat Bishop Dept. for Social Insurance 275 Main Street, 3rd Fl. Frankfort, KY 40621 Ph: (502) 564-4847 Fax: (502) 564-6907	Mr. Rich Eversman Dept. for Social Insurance Ph: (502) 564-4847	NEAT/MHEA *and* priority list	None	None	None	No

Table A.1. Continued

State	Initial contact	Other contact recommended for additional information	Technique(s) used to select weatherization measures	Data system(s) that could be used to measure program performance	Evaluation(s) completed or documented between April 1996 and September 1998	Planned evaluation(s) to be completed after September 1998	State evaluation results used in meta evaluation?
Louisiana	Ms. Brenda Grogan Louisiana Dept. of Social Services P.O. Box 3318 Baton Rouge, La 70821 Ph: (504) 342-5278 Fax: (504) 342-4038	None	NEAT, MHEA	None	None	Will consider doing future evaluation	No
Maine	Mr. Warren Cunningham Maine State Housing Authority 353 Water Street Augusta, ME 04330-4633 Ph: (207) 626-4600 Fax: (207) 626-4878	Mr. Tony Gill Maine State Housing Authority Ph: (207) 626-4651	Computer-aided audit system using MEADOW 96 software (developed in Maine)	MEADOW 96 calculates savings to investment ratio for each weatherization task and the whole job	None	Will use pre- and post-weatherization billing data to correlate measures installed with savings	No
Maryland	Ms. Eileen Hagan Maryland Dept. of Housing and Community Development 100 Community Place Crownsville, MD 21032-2023 Ph: (410) 514-7542 Fax: (410) 514-7499	None	Priority list	Currently working on development of a data system to measure program performance	None	None	No
Massachusetts	Mr. Ken Rauseo Dept. of Housing and Community Development 100 Cambridge St., Room 1803 Boston, MA 02202 Ph: (617) 727-7004 Fax: (617) 727-4259	None	NEAT and priority lists based on NEAT results	Data base containing all Building Weatherization Reports submitted by subgrantees, showing installed measures, costs, heating system type and fuel, and client information	None	None	No
Michigan	Ms. Lynda Crandall MI Dept. of Social Services P.O. Box 30037 Lansing, MI 48909 Ph: (517) 335-3094 Fax: (517) 335-7771	None	NEAT and priority lists based on NEAT results	None	None	None	No

Table A.1. Continued

State	Initial contact	Other contact recommended for additional information	Technique(s) used to select weatherization measures	Data system(s) that could be used to measure program performance	Evaluation(s) completed or documented between April 1996 and September 1998	Planned evaluation(s) to be completed after September 1998	State evaluation results used in meta evaluation?
Minnesota	Mr. Mark Kaszynski Dept. of Children, Families, and Learning 550 Cedar Street St. Paul, MN 55101 Ph: (651) 582-8566 Fax: (651) 582-8490	Ms. Carol Raabe Dept. of Children, Families, and Learning Ph: (651) 582-8431	SIR Audit, using NEAT engineering calculations and local costs to identify cost-effective measures	Achieved Savings Assessment Program, using run-time data loggers and custom-designed software	Achieved Savings Assessment Program measured energy savings for 1995–1996 and 1996–1997 program years	Ongoing annual assessments of weatherization program energy savings	Yes
Mississippi	Mr. Bobby Pamplin Dept. of Human Services 750 N. State Street, 6th Floor Jackson, MS 39202 Ph: (601) 359-4775 Fax: (601) 359-4370	Ms. Sollie B. Norwood Dept. of Human Services Ph: (601) 359-4768	NEAT *and* priority list	Data on projected costs and energy savings produced by NEAT audits	None	None	No
Missouri	Ms. Cher Stuewe-Portnoff Division of Energy P.O. Box 176 Jefferson City, MO 65102 Ph: (573) 751-4000 Fax: (573) 751-6860	Ms. Lesa Jenkins Dept. of Natural Resources Ph: (573) 751-8593	NEAT *and* priority list for mobile homes (but will implement MHEA in FY 1999)	None	None	None	No
Montana	Mr. Jim Nolan Dept. of Social and Rehabilitation Services P.O. Box 4210 Helena, MT 59604 Ph: (406) 447-4260 Fax: (406) 447-4287	Mr. Kane Quenemoen State of Montana Ph: (406) 447-4267	Montana Energy Audit	Oracle (client-tracking data base)	Evaluation of energy savings from 1995–1996 weatherization program	None	No, because results are not comparable to other studies
Nebraska	Mr. Peter Davis Nebraska Energy Office P.O. Box 95085 Lincoln, NE 68509 Ph: (402) 471-2867 Fax: (402) 471-3064	None	NEAT *and* priority list for mobile homes	None	Report documenting evaluation of energy and cost savings was completed in August 1996	None	No, because findings were used in 1996 meta evaluation
Nevada	Mr. Craig Davis Nevada State Welfare Division 2527 N. Carson Street Carson City, NV 89710 Ph: (702) 687-4258, ext. 226 Fax: (702) 687-4040	None	REM Design Audit *and* priority list and recommen-dations based on blower door and combustion appliance safety tests	None	None	None	No

Table A.1. Continued

State	Initial contact	Other contact recommended for additional information	Technique(s) used to select weatherization measures	Data system(s) that could be used to measure program performance	Evaluation(s) completed or documented between April 1996 and September 1998	Planned evaluation(s) to be completed after September 1998	State evaluation results used in meta evaluation?
New Hampshire	Mr. Mitch Koenig Governor's Office of Energy and Community Services 57 Regional Drive Concord, NH 03301-8506 Ph: (603) 271-2611 Fax: (603) 271-2615	None	NEAT and priority list for mobile homes	New data base	None	None	No
New Jersey	Ms. Clarice Sabree NJ Dept. of Community Affairs 101 S. Broad CN-814 Trenton, NJ 08625 Ph: (609) 984-3301 Fax: (609) 292-9798	None	EA-QUIP (Energy Audit)	None	None	None	No
New Mexico	Mr. Lionel Holguin NM Mortgage Finance Authority 344 Fourth Street, SW Albuquerque, NM 87102 Ph: (505) 843-6880 Fax: (505) 243-3289	None	NEAT *plus* Retro-tech for mobile homes *plus* priority lists	Will install WIN SAGA in late 1998 to track weatherization results.	None	State plans to initiate an analysis program	No
New York	Mr. Patrick Sweeney NYS Division of Housing and Community Renewal 38–40 State Street Albany, NY 12207 Ph: (518) 474-5700 Fax: (518) 486-4663	Mr. J. Patrick Connolly Energy Services Bureau Ph: (518) 474-5700	Targeted Investment Protocol System (TIPS) Audit	Subgrantees collect pre- and post-weatherization billing data	Average energy savings were calculated for a representative sample of buildings weatherized over the past four program years, using pre- and post-weatherization billing data	Subgrantees continue to collect pre- and post-weatherization data and state continues to analyze energy savings on an ongoing basis	No, because results are not comparable to other studies
North Carolina	Mr. Percy Carter Dept. of Commerce 430 N. Salisbury Street Raleigh, NC 27611 Ph: (919) 733-1904 Fax: (919) 733-2953	Mr. Eugene Mesley N.C. Energy Division Ph: (919) 733-0518	NEAT 2.1 and MHEA	Statewide client information data base showing characteristics of weatherized units, measures installed, costs, and projected savings	None	None	No

Table A.1. Continued

State	Initial contact	Other contact recommended for additional information	Technique(s) used to select weatherization measures	Data system(s) that could be used to measure program performance	Evaluation(s) completed or documented between April 1996 and September 1998	Planned evaluation(s) to be completed after September 1998	State evaluation results used in meta evaluation?
North Dakota	Mr. Howard Sage Office of Intergovernmental Assistance 600 East Blvd., 14th Floor Bismarck, ND 58505 Ph: (701) 328-2094 Fax: (701) 328-2308	None	WXEOR	None	None	None	No
Ohio	Ms. Sara Ward Ohio Dept. of Development P.O. Box 1001 Columbus, OH 43266-0101 Ph: (614) 466-6954 Fax: (614) 466-4708	Mr. Stjepan Vlahovich Ohio Office of Energy Efficiency Ph: (614) 466-0545	NEAT *and* priority list based on NEAT	Integrated application for tracking information on grants, budgets, and other activities. Also has access to energy use data for subset of customers.	Analysis of 1994 program, including energy and cost savings	None	Yes
Oklahoma	Ms. Kathy McLaughlin OK Dept. of Commerce P.O. Box 26980 Oklahoma City, OK 73126-0980 Ph: (405) 815-5339 Fax: (405) 815-5344	Mr. Mark Thompson Forefront Economics Ph: (503) 626-1657	NEAT	None	None	State may do analysis of effect of new audit technique on energy usage	No
Oregon	Mr. Jack Hruska OR Housing and Community Services Dept. 123 N.E. 3rd , Suite 3470 Convention Center Plaza Portland, OR 97232 Ph: (503) 230-8011, ext. 231 Fax: (503) 230-8863	Mr. Kevin Nehila OR Housing and Community Services Dept.	Computerized audit using WEXOR	None (but one is under construction)	Preliminary findings from initial study of REACH program (which has a weatherization component)	Continuation of REACH evaluation and possibly an evaluation of a proposed utility pilot program that targets high energy users	No, because preliminary findings are not weather-normalized
Pennsylvania	Mr. Tony Kimmel Dept. of Community and Economic Development Community Empowerment Office Room 352, Forum Building Harrisburg, PA 17120 Ph: (717) 787-1984 Fax: (717) 234-4560	None	NEAT	None	None	None	No

Table A.1. Continued

State	Initial contact	Other contact recommended for additional information	Technique(s) used to select weatherization measures	Data system(s) that could be used to measure program performance	Evaluation(s) completed or documented between April 1996 and September 1998	Planned evaluation(s) to be completed after September 1998	State evaluation results used in meta evaluation?
Rhode Island	Mr. Michael Snitzer Governor's Office of Energy Assistance 275 Westminster Mall Providence, RI 02903 Ph: (401) 277-6920 Fax: (401) 222-1260	None	NEAT	None	None	None	No
South Carolina	Mr. Holcombe Smith Office of the Governor 1205 Pendelton Street Columbia, SC 29201 Ph: (803) 734-0684 Fax: (803) 734-0356	None	Computerized audit and priority list	Statewide client information data base showing characteristics of weatherized units and projected savings	None	Would like to start tracking actual energy savings	No
South Dakota	Ms. Abbie Rathbun Dept. of Social Services 206 W. Missouri Avenue Pierre, SD 57501-4517 Ph: (605) 773-3668 Fax: (605) 773-6657	None	NEAT	None	None	None	No
Tennessee	Mr. Steve Neece Dept. of Human Services 400 Deaderick Street Nashville, TN 37248-9500 Ph: (615) 313-4765 Fax: (615) 532-9956	Ms. Zelma Waller Dept. of Human Services Ph: (615) 313-4766	NEAT and priority list	None	None	None	No
Texas	Ms. Peggy Colvin Texas Department of Housing and Community Affairs Energy Assistance Section 507 Sabine St., Suite 400 Austin, TX 78711-3941 Ph: (512) 475-3864	Ms. Wendy Pollard Ph: (512) 475-2559 Fax: (512) 475-3935	EASY Audit	EASY Audit files are stored electronically	None	Analysis of energy savings from homes weatherized between January 1, 1997, and September 31, 1997 with assistance from ORNL	No
Utah	Mr. Michael Johnson Office of Energy Services 324 S. State Street, Suite 230 Salt Lake City, UT 84111 Ph: (801) 538-8657 Fax: (801) 538-8660	None	NEAT	Collects data for each home weatherized, including demographics, consumption and improvements	None	None	No

Table A.1. Continued

State	Initial contact	Other contact recommended for additional information	Technique(s) used to select weatherization measures	Data system(s) that could be used to measure program performance	Evaluation(s) completed or documented between April 1996 and September 1998	Planned evaluation(s) to be completed after September 1998	State evaluation results used in meta evaluation?
Vermont	Mr. Jules Junker Office of Economic Opportunity 103 S. Main Street Waterbury, VT 05676-1801 Ph: (802) 241-2452 Fax: (802) 241-1225	None	"Market Manager" Audit System	Weatherization Data Management System (WDMS) collects information on buildings, measures installed, costs of measures, and fuel consumption	Impact evaluation of Vermont's Weatherization Assistance Program completed in December 1997	Subsequent evaluations planned at two year intervals	Yes
Virginia	Mr. William Beachy Division of Housing 501 2nd Street Richmond, VA 23219-1747 Ph: (804) 371-7112 Fax: (804) 371-7091	None	Priority list supported by NEAT	None	None	None	No
Washington	Mr. Steve Payne Department of Community, Trade and Economic Development 906 Columbia Street SW P.O. Box 48300 Olympia, WA 98504 Ph: (360) 586-8980 Fax: (360) 586-5880	Ms. Carolyn Wyman Ph: (360) 586-0495	NEAT *and* a priority matrix created from NEAT	None	None	Analysis of savings from homes weatherized between June 1996 and June 1998 with assistance from ORNL	No
West Virginia	Mr. Bob Scott WV Office of Economic Opportunity 950 Kanawha Blvd. East Charleston, WV 25301 Ph: (304) 558-8860 Fax: (304) 558-4210	None	Priority list based on NEAT	Data base that includes information on installed measures, blower door readings, and insulation levels, to provide data for future energy savings evaluations	None	State plans to evaluate utility project sometime in the future, using a yet-to-be developed model evaluation tool that will be provided by DOE's Philadelphia Support Office	No
Wisconsin	Mr. Gary Gorlen Division of Housing, 4th Floor P.O. Box 8944 Madison, WI 53708-8944 Ph: (608) 266-6789 Fax: (608) 264-6688	None	Wisconsin Energy Conservation Corporation (WECC) v. 4.0	None	None	Comparison of pre- and post-weatherization furnace run-time for 30–40 homes	No

Table A.1. Continued

State	Initial contact	Other contact recommended for additional information	Technique(s) used to select weatherization measures	Data system(s) that could be used to measure program performance	Evaluation(s) completed or documented between April 1996 and September 1998	*Planned evaluation(s)* to be completed after September 1998	State evaluation results used in *meta evaluation?*
Wyoming	Ms. Jan Stiles Dept. of Family Services Hathaway Bldg., 3rd Floor Cheyenne, WY 82002 Ph: (307) 777-6137 Fax: (307) 777-7747	Ms. Rana Belshe Conservation Connection Consulting Ph: (715) 334-2707	NEAT, *in* conjunction with fuel indexing	None	None	Final documentation of 1994–1995 and 1995–1996 weatherization program savings	No

APPENDIX B

ELECTRICITY SAVINGS

B.1 SAVINGS BY ELECTRICALLY-HEATED HOUSES

Mean values for pre-weatherization energy consumption, weatherization-induced energy savings, and savings as a percent of pre-weatherization consumption were calculated from the average values reported in the three state studies of electrically-heated houses.[10] These studies reported electricity use and savings in terms of kilowatt hours (kWh) metered at the household level, and we converted this to BTUs by multiplying the number of kWh by 3,413. Mean annual pre-weatherization consumption for all end uses was 68.4 million BTUs per household; mean household energy savings amounted to 6.0 million BTUs annually; and mean energy savings equaled 9.1% of pre-weatherization consumption. These values, plus the minimum and maximum and 90% confidence interval for each variable, are shown in Table B.1. Because the sample size was very small (only three studies), the confidence intervals are substantially greater than those reported in Chapter 3 for the gas-fueled structures. For example, there is a 90% probability that *average* savings for the entire population of electrically-heated houses will fall somewhere between 3.2% and 15.1% of pre-weatherization consumption, which represents an extremely broad range.

Table B.1. Key findings from three state weatherization program studies of electric-heated structures

	Minimum	Maximum	Mean	90% confidence interval
Pre-weatherization consumption for all end uses (MBTU)	60.3	73.2	68.4	56.5–80.3
Absolute savings* (MBTU)	4.5	7.5	6.0	3.5–8.5
Savings as a percent of pre-weatherization consumption (%)	6.3	13.1	9.1	3.2–15.1

*These numbers are calculated from net savings in those cases where a control group was used and gross savings in all other cases.

[10]The three studies of electrically-heated houses were performed by Delaware, the District of Columbia, and Ohio.

B.2 SAVINGS BY HOUSES USING ELECTRICITY FOR NON-HEATING PURPOSES

This metaevaluation examined four state studies of houses that use electricity for non-heating purposes.[11] From the average values reported in these studies, we calculated mean values for pre-weatherization energy consumption, weatherization-induced energy savings, and savings as a percent of pre-weatherization consumption.[12] As shown in Table B.2, mean annual pre-weatherization consumption was 27.9 million BTUs per household; mean household energy savings were 1.0 million BTUs annually; and mean energy savings amounted to 2.3% of pre-weatherization consumption. These values are much smaller than those reported for electrically-heated houses but this is not surprising because heating—a major consumer of energy and target for energy savings in most houses—is not addressed. Once again, the sample size (four studies) is small and the confidence intervals are relatively large. Accordingly, there is a 90% chance that *average* savings for the entire population of houses using electricity for non-heating purposes falls somewhere between -2.3%[13] and 6.7% of pre-weatherization consumption.

Table B.2. Key findings from four state weatherization program studies of non-heating electricity use

	Minimum	Maximum	Mean	90% confidence interval
Pre-weatherization consumption (MBTU)*	23.5	32.2	27.9	0.4–55.3
Absolute savings** (MBTU)	0.4	1.3	1.0	0.5–1.4
Savings as a percent of pre-weatherization consumption (%)*.	1.6	3	2.3	-2.1–6.7

*Absolute savings were reported by four states, but only two states had good data on pre-weatherization consumption and savings as a percent of that.

**These numbers are calculated from net savings in those cases where a control group was used and gross savings in all other cases.

[11]The four studies of houses using electricity for non-heating purposes were performed by Colorado, Iowa (two studies), and Vermont.

[12]Like the studies of electrically-heated houses, these studies reported electricity use and savings in terms of kWh at the point of consumption and we converted those numbers to BTUs by multiplying by 3,413.

[13]A negative savings means that energy use actually increases following weatherization, which is clearly counterintuitive.

APPENDIX C

INDEPENDENT VARIABLES USED IN REGRESSION ANALYSIS

Four independent variables were used in the regression analysis of natural gas savings: (1) pre-weatherization energy consumption; (2) square footage of weatherized structures; (3) heating degree days in the project area; and (4) weatherization expenditures. The minimum, maximum, and mean values for each of these variables, along with the number of observations, are presented in Table C.1. Where possible, these data were extracted from reports documenting the state studies or from follow-up contacts with state weatherization staff. If a state did not directly provide heating degree days, this information was taken from a National Oceanic and Atmospheric Administration compilation (Heim, Garvin, and Nicodemus 1993) of long-term population-weighted heating degree days for the states. In five cases, the state contact could not provide the average square footage for the weatherized structures so we used the national average of 1149 square feet per weatherized single family detached unit (Brown, Berry, Balzer, and Faby 1993). Six of the nine studies of gas-fueled residences reported agency expenditures. Three reported these expenditures for 1996 and the others reported expenditures for previous years. Expenditures made in years prior to 1996 were converted to 1996 dollars using an adjustment factor to account for inflation. In those instances where information on agency expenditures was not available, we did not attempt to provide an estimate for this variable because of the potential for introducing substantial error.

Table C.1. Values of independent variables used in regression analysis of natural gas savings

	Number of observations	Minimum	Maximum	Mean
Pre-weatherization consumption (MBTU)	9	102.3	190.2	148.9
Square footage of structures	9	1006.0	1270.0	1141.8
Heating degree days	9	4455	7903	6436.7
Weatherization expenditures (1996 dollars)	6	720.00	3081.00	2169.76

Table C.2 shows the findings of a correlation analysis run on the set of four independent variables used in this evaluation. As this table illustrates, the strongest correlations were between (1) square footage of structures and weatherization expenditures ($r=0.675$, $p=.14$); and (2) square footage of structures and pre-weatherization energy consumption ($r=0.591$, $p=.09$). When we excluded one study focusing on households with abnormally high values for pre-weatherization consumption from the data set, we found that the relationship between pre-weatherization energy consumption and heating degree days was strengthened (r=0.516, p=.19). However, none of these relationships was significant at the .05 level.

Table C.2. Correlations among independent variables used in regression analysis of natural gas savings

	Square footage of structures	Heating degree days	Weatherization expenditures
Pre-weatherization consumption	r = 0.591 p = .09	r = 0.225 p = .56	r = 0.374 p = .47
Square footage of structures		r = −0.479 p = .16	r = 0.675 p = .14
Heating degree days			r = −0.104 p = .84

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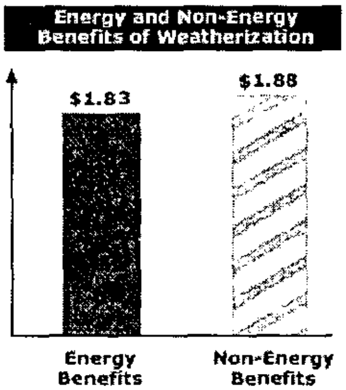

Each dollar of DOE investment in weatherization returns $3.71 in energy- and non-energy-related benefits.

Non-Energy Benefits of Weatherizati

There are substantial non-energy benefits from DOE's Weatherizat Assistance Program, according to a new study by Oak Ridge Natio Laboratory (ORNL). The study documents benefits to utility ratepa the economy, and the environment that are in addition to the ene benefits that reduce the energy bills of low-income families by inc the energy efficiency of their homes.

- **How to value non-energy benefits of weatherization?**
- **Read this and other reports by Oak Ridge National Lat**

How to value non-energy benefits of weatherization?

The U.S. Department of Energy (DOE) issued a press release on August 28, 2002 announcing a documenting considerable non-energy benefits from low-income weatherization. The report sum existing literature on how to value such benefits for participating households, utility ratepayers, economy, and the environment. While there is a large range of potential monetary values for th benefits, there is no question they are important for the communities that receive weatherizatio services.

Furthermore, ORNL's analyses are useful for developing overall cost-benefit ratios. Researchers that for every dollar of DOE investment, there are non-energy benefits worth $1.88.

These benefits are in addition to energy savings, which reduce energy bills an average of $275 p in more than 105,000 low-income homes in 2002. The cost-benefit ratio of energy reduction is $ each dollar of DOE investment. When the energy- and non-energy-related benefits are added to the DOE Weatherization Assistance Program returns $3.71 for every dollar invested by DOE.

Among others, the non-energy benefits of weatherization include:

- **For participating households**, there are reduced water consumption and accompanying and sewer fees, and an increase in property values.
- **For utility ratepayers**, there are reduced costs for bill collection and service shut-offs. A because weatherization addresses the safety of major appliances, the utility has fewer em calls.
- **For the local economy**, DOE's investment in energy efficiency generates a whole range local home services industries. Nationwide, the Weatherization Assistance Program genera 8,000 jobs, which increases the tax base in communities throughout the country and indir supports other jobs. Furthermore, weatherization reduces the burden of unemployment pa for taxpayers and local businesses.
- **For national security**, weatherization decreases U.S. energy use the equivalent of 15 mi barrels of oil every year.

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- **For the environment**, the reduction in energy consumption by low-income clients reduce need for combustion of fossil fuels and the resulting emissions into the atmosphere.

The report noted that there are additional benefits from weatherization that are not covered in t because a monetary value cannot be assigned to them.

Read this and other reports by Oak Ridge National Laboratory

Non-Energy Benefits from the Weatherization Assistance Program—A Summary of Findings from Literature (PDF 235 KB) Download Acrobat Reader.

Martin Schweizer and Bruce Tonn; Oak Ridge National Laboratory report number ORNL/CON-48 pp.; April 2002.

Recent Studies and Publications
The Oak Ridge National Laboratory (ORNL) Weatherization and SEP Support Program have publi dozens of reports over the past 17 years, many of which are available online. Some hard copies reports are also available from ORNL.

ORNL/CON-484

NONENERGY BENEFITS FROM THE WEATHERIZATION ASSISTANCE PROGRAM: A SUMMARY OF FINDINGS FROM THE RECENT LITERATURE

Martin Schweitzer
Bruce Tonn

OAK RIDGE NATIONAL LABORATORY

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NONENERGY BENEFITS FROM THE WEATHERIZATION ASSISTANCE PROGRAM: A SUMMARY OF FINDINGS FROM THE RECENT LITERATURE

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Date Published: April 2002

Prepared for
U. S. Department of Energy
Office of Building Technology Assistance
Budget Activity Number EC 17 01 00 0

Prepared by
OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37831
managed by
UT-BATTELLE, LLC
for the
U.S. DEPARTMENT OF ENERGY
under contract DE-AC05-00OR22725

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EXECUTIVE SUMMARY

The purpose of this project is to summarize findings reported in the recent literature on nonenergy benefits attributable to the weatherizing of low income homes. This study is a follow-up to the seminal research conducted on the nonenergy benefits attributable to the Department of Energy's national Weatherization Assistance Program by Brown et al. (1993).

For this review, nonenergy benefits were broken into three major categories: (1) ratepayer benefits; (2) household benefits; and (3) societal benefits. The ratepayer benefits can be divided into two main subcategories: payment-related benefits and service provision benefits. Similarly, there are two key types of household benefits: those associated with affordable housing and those related to safety, health, and comfort. Societal benefits can be classified as either environmental, social, or economic.

Fig. E.S. 1 presents point estimates of the average lifetime monetary value per weatherized home resulting from low income weatherization programs for the key benefit types listed above. These benefits represent net present value estimates (i.e., estimates of the current

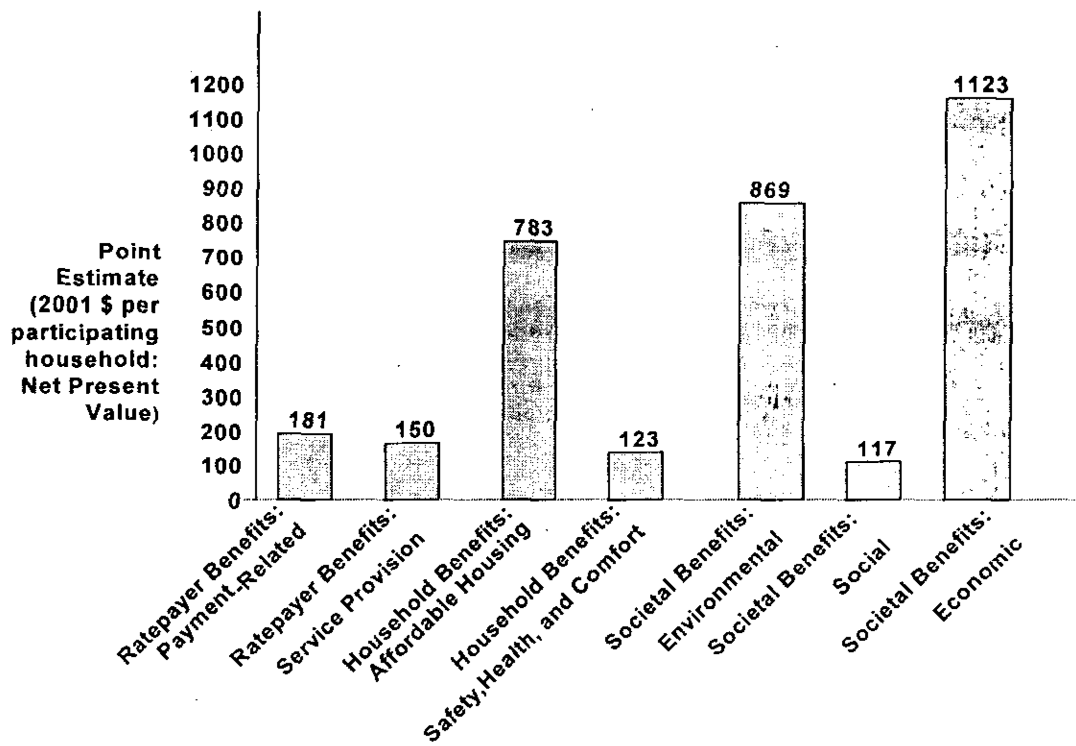

Fig. E.S.1 Summary of Nonenergy Benefits by Category and Subcategory

worth of all benefits expected over the lifetime of the weatherization measures), assuming a 20-year lifetime for installed energy efficiency measures and a 3.2% discount rate. Overall, societal benefits are estimated to be substantially larger than ratepayer and household benefits. *Ranges* for the societal benefits are also much greater than for the other two categories of nonenergy benefits. The total monetized value for all nonenergy benefit categories associated with weatherizing a home is estimated to be $3346, in 2001 dollars. This represents a national average which, like any point estimate, has considerable uncertainty associated with it. This figure is substantially higher than the total value of nonenergy benefits presented a decade ago in the national weatherization evaluation (Brown et al. 1993) because the current study quantified a much broader array of benefits than did the earlier work.

The net present value of $3346 for all nonenergy benefits is slightly greater than the average net present value of energy savings for houses heated by natural gas, which is $3174 in 2001 dollars. In comparison, the average total cost per weatherization is $1779, also in 2001 dollars. The "societal" benefit/cost ratio, which compares *all* benefits to *all* costs, is approximately 3.7. Low and high values for the societal benefit/cost ratio, using low and high nonenergy benefit estimates, are 2.0 and 52.5, respectively. It should be noted that the total monetized nonenergy benefit estimate is lower than it could be because the estimate does not contain some benefits that have not been expressed in monetary terms.

1. INTRODUCTION

1.1 BACKGROUND

The national Weatherization Assistance Program provides energy efficiency improvements for low-income residences throughout the country. The program is sponsored by the U.S. Department of Energy and is implemented by state and local agencies in all 50 states and the District of Columbia. Since its inception in 1976, the Weatherization Assistance Program has weatherized approximately five million dwelling units for their low-income occupants. Common weatherization measures include: caulking and weather stripping around doors and windows and sealing other unnecessary openings to reduce air infiltration; installing attic, wall, and floor insulation; and wrapping water heaters and pipes with insulating material. A national evaluation of the program conducted by Oak Ridge National Laboratory (ORNL) almost a decade ago (Brown et al. 1993) focused on energy and cost savings, but it also contained a detailed discussion of the nonenergy benefits associated with low-income weatherization activities. Since the time of the national evaluation, a substantial amount of research has been conducted to examine the nature and magnitude of the nonenergy benefits that result from weatherization programs. The purpose of this report is to use the findings from the large body of post-1993 research to update ORNL's previous estimates of the Weatherization Assistance Program's nonenergy benefits.

ORNL's national weatherization evaluation (Brown et al. 1993) identified an extensive range of nonenergy benefits associated with the Weatherization Assistance Program. A total of fifteen benefits were identified, but monetized values could be calculated for only about half of them. As shown in Table 1, all the monetized values combined had a net present value, over the lifetime of the weatherization measures installed, of $976 (in 1989 $).

1.2 METHODS

The primary research method used for this study was a comprehensive review of the literature on nonenergy benefits written since the national weatherization evaluation was completed in 1993. Many different articles and reports have been written about the nonenergy benefits of low-income weatherization activities since that time. Some present the findings from primary research conducted on the subject, usually focusing on a weatherization program operated by a given state or utility company (e.g., Magouirk 1995; Blasnik 1997; Hill et al. 1998). Others take a meta-analysis approach and report the findings from a number of studies conducted in different locations (e.g., Riggert et al. 1999; Riggert et al. 2000; Howat and Oppenheim 1999). One set of articles that was especially useful for this study (Skumatz and Dickerson 1997; Skumatz and Dickerson 1998; Skumatz and Dickerson 1999) focused on two

Table 1. Nonenergy Benefits Monetized in National Weatherization Evaluation (1993)

Nonenergy Benefit	Net Present Value of Benefit per Dwelling (1989 $)
Enhanced property value and extended lifetime of dwelling	126
Reduced fires	3
Reduced arrearages	32
Federal taxes generated from direct employment	55
Income generated from indirect employment	506
Avoided costs of unemployment benefits	82
Environmental externalities	172
Total of all nonenergy benefits	**$976**

low-income weatherization programs operated by Pacific Gas and Electric Company (PG&E), using primary data pertaining to those programs and also making use of important findings from a comprehensive review of studies performed by other researchers elsewhere in the country. Because much of the information analyzed by Skumatz and Dickerson came from a variety of locations, and because the PG&E programs they studied are very similar to other full-scale weatherization efforts undertaken throughout the country, the findings from the Skumatz and Dickerson articles are considered broadly applicable to DOE's Weatherization Assistance Program.

From a thorough review of the literature, we identified a complete set of nonenergy benefits and organized them into major categories and subcategories. Our approach was informed by the post-1993 articles and reports reviewed as well as by the ideas presented in the national weatherization evaluation (Brown et al. 1993). Then, a range of monetary values was identified for each nonenergy benefit, drawing from all recent studies that provided dollar values for nonenergy benefits and that employed methods that we considered reasonable and legitimate, even if the numbers themselves appeared to be somewhat extreme. In fact, many of the value ranges presented in this report are very broad.

After a range of monetized values was identified from the literature for all nonenergy benefits, we used our professional judgment to select a reasonable point estimate for each one to represent the average value of that benefit associated with weatherization efforts nationwide. Even where the entire continuum of possible values was very large, it was common for *most* of the suggested values to cluster around a fairly narrow range. In such cases, we tended to select a preferred point estimate that was close to the midpoint of the clustered values. Where one extremely high value led to an extended range, it was often the case that the clustered values and our point estimate fell toward the low end of that range. However, it is important to note the inherent uncertainty associated with any point estimate that is made. Clearly, a single point estimate for any given nonenergy benefit cannot represent the benefits associated with every weatherization effort in each separate locale because of the substantial variation that occurs among different programs and geographic areas. Even where, as in this report, a point estimate is based on a number of different studies and is intended to represent a national average, there is still good reason to be cautious. As the name implies, a point estimate is only an *estimate* of a savings value and is based on various assumptions about program operations and effectiveness rather than on systematic measurement, and subsequent weighting and averaging, of program outcomes throughout the country.

Nearly all of the nonenergy benefits addressed in this report occur everywhere, but a couple only apply to certain types of households (i.e., those receiving low-income rate subsidies or those using natural gas). In such cases, the magnitude of the benefits reported in the literature is adjusted downward to make it an average value for the entire nation. Of course, even where benefits do apply universally, the actual magnitude will vary from place to place, as noted above. When point estimates for all the benefits addressed in this report are aggregated, they represent the average benefit for a typical low-income U.S. household. However, that point estimate will not necessarily apply to each individual household. In cases where a particular benefit does not apply, the total value of all nonenergy benefits would tend to be lower than indicated in this report, provided that all other conditions affecting the magnitude of benefits are typical.

Monetary values for the various nonenergy benefits provided in the recent articles and reports that we reviewed are generally treated as if they are in 2001 dollars. We consider this to be a reasonable approach because (1) most of the works reviewed were written during the last two or three years and inflation has been very modest during that period, and (2) the dollar values provided in the literature tend to be estimates and approximations and are not precise enough to warrant adjustment by a few percentage points. The principal exception to this is in the case of values that are taken from the national weatherization evaluation (Brown et al. 1993). Because the data in that study date from 1989, it was considered prudent to adjust the relevant numbers upward, using the inflation factors contained in the Consumer Price Index (Bureau of Labor Statistics 2001).

Many of the monetized values presented in the literature are listed in terms of dollars per participating household per year. We converted those annual benefits into net present value (NPV) per household, assuming that: (1) the useful life of the installed weatherization measures is 20 years (which is consistent with past evaluations of the Weatherization Assistance Program); and (2) the appropriate discount rate is 3.2 % (the rate suggested by the Office of Management and Budget for program evaluation). Based on these assumptions, a benefit that has an annual value of $10 per year would have a NPV of $146. We are aware that different parties are likely to apply different discount rates when calculating the value of a given investment. However, the 3.2% discount rate is used in this report for *all* categories of benefits to be consistent and to reflect the fact that this document is written from the perspective of the federal agency that sponsors the Weatherization Assistance Program.

1.3 SCOPE OF REPORT

The subsequent chapters of this report present key findings from our study of the nonenergy benefits associated with low-income weatherization efforts. In order to present a complete picture of the nonenergy benefits associated with weatherization programs, these benefits are described from three distinct perspectives: that of utility ratepayers; that of participating households; and that of society as a whole. It should be noted that a couple of the nonenergy benefits addressed in this report are discussed under more than one major category, to reflect the fact that there are different groups of beneficiaries. For example, "avoided shut-offs and reconnections" are discussed both from the ratepayer and the household perspective. The value of the benefit received by each set of actors in different, and double-counting is avoided because ratepayers and participating households receive different, and non-overlapping, values from the benefit in question.

Chapter 2 discusses the benefits received by utility companies and passed on to their ratepayers. These fall under the broad headings of benefits related to the payments that utilities receive from their customers and benefits related to the utilities' provision of services. In this chapter, as in the following ones, each individual benefit is described, a range of possible monetized values and a point estimate are given for each benefit, and a brief explanation is provided of the methods used to calculate the values.

In Chapter 3, benefits experienced by the low-income households that receive weatherization services are described. Such benefits can be grouped into two categories: affordable housing benefits and benefits related to the occupants' safety, health, and comfort.

Chapter 4 addresses societal benefits, which can be subdivided into environmental benefits, social benefits, and economic benefits.

Finally, Chapter 5 summarizes the full set of nonenergy benefits and their monetary values, examines the relative magnitude of the different types of nonenergy benefits, and compares the size of these benefits with the energy benefits generated by the Weatherization Assistance Program.

2. RATEPAYER BENEFITS

Utility ratepayers receive two distinct types of nonenergy benefits as a result of low-income weatherization efforts. Point estimates of the average lifetime monetary value associated with each type of benefit are shown in Fig. 1. The first type of benefit is related to the payments that utilities receive (or do not receive) from their customers and includes six different items: (1) avoided rate subsidies; (2) lower bad debt write-off; (3) reduced carrying cost on arrearages; (4) fewer notices and customer calls; (5) fewer shut-offs and reconnections for delinquency; and (6) reduced collection costs. The second type of benefit is related to the provision of services and has three components: (1) fewer emergency gas service calls; (2) transmission and distribution (T&D) loss reduction; and (3) insurance savings. While all of the benefits listed above initially accrue to utility companies, they tend to be passed on to the utilities' customers and are therefore classified in this report as ratepayer benefits. Each of these benefits is discussed in more detail below.

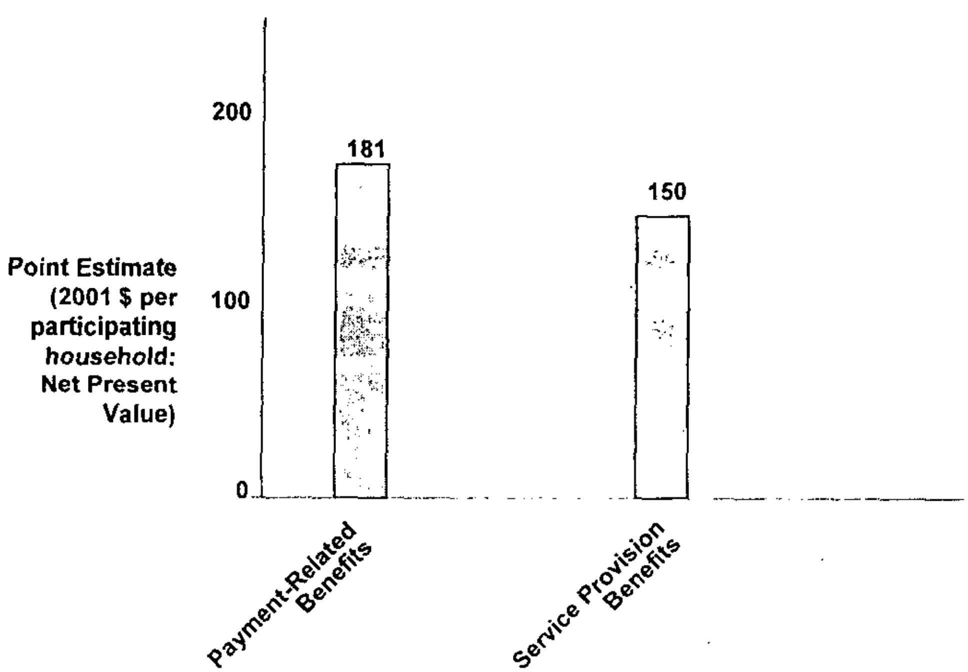

Fig. 1. Average Lifetime Monetary Value of Ratepayer Benefits, by Type

2.1 PAYMENT-RELATED BENEFITS

Rate Subsidies Avoided

Many utilities provide lower, subsidized rates for their low-income customers. Accordingly, each unit of energy consumed by low-income customers represents an expense for the utility and for its other customers, whose payments help subsidize the discount rate. When the amount of energy used by low-income customers is reduced as a result of a weatherization program, the number of subsidized units of energy sold decreases and the utility and its other ratepayers save money.

The literature reviewed for this study presented a number of different estimates of the dollar value of rate subsidies avoided as a result of low-income weatherization programs. Many of these estimates were presented in terms of annual savings per household but, as explained in Chapter 1, these were all converted to net present value over the lifetime of the measures installed. The estimated lifetime savings range from a low of $38 to a high of $467. However, the estimates of benefits found in the literature typically describe only those instances in which rate subsidies are available and used by low-income customers. In order to represent average savings across the nation as a whole, those savings numbers should be adjusted downward to reflect the proportion of low-income customers actually receiving such subsidies. Based on information compiled by the National Center for Appropriate Technology (2001), we know that only about 15% of low-income customers nationwide get rate subsidies. Accordingly, we multiplied the range of benefits presented in the literature by 0.15, resulting in an adjusted range of $6 to $70 (Table 2). Our preferred point estimate for this benefit is $21 but, as explained previously, any single estimate made for the entire low-income Weatherization Assistance Program is necessarily imprecise and the associated uncertainty must be recognized.

Table 2. Ratepayer Benefits: Payment-Related

Nonenergy Benefit	**Range of Benefits (in 2001 $ per participating household: Net Present Value)**	**Point Estimate of Benefits (in 2001 $ per participating household: Net Present Value)**
Rate subsidies avoided	6 - 70	21
Lower bad debt write-off	15-3462	89
Reduced carrying cost on arrearages	4-110	57
Fewer notices and customer calls	0-23	6
Fewer shut-offs and reconnections for delinquency	2-15	8
Reduced collection costs	Not Available	Not Available

The point estimate of $21 suggested above is derived from the midpoint of the range of possible dollar savings from avoided rate subsidies presented by Skumatz and Dickerson (1999) for the Low-Income Weatherization Program operated by PG&E. The savings estimate was calculated by taking the average rate subsidy received by participating households and multiplying it by the amount (in percentage terms) by which participants' energy use is likely to be reduced. We then adjusted this amount downward, as described above, to make it represent the average savings distributed over *all* low-income customers and not just those receiving rate discounts.

Lower Bad Debt Write-off

When customers cannot pay all or part of their bills for an extended period of time, the utility might have to write off the unpaid portion as bad debt. When the occupants of weatherized units experience reductions in their utility bills, they are better able to make their payments and the amount of bad debt written off is likely to decrease. Actually, there are two parts to this reduction in bad debt: a decrease in the average size of bad debt written off and a decline in the number of such accounts.

The range of possible dollar benefits presented in the literature for lower bad debt write-off was extremely broad, with a minimum NPV of $15 and a maximum of $3462 (Table 2). Although one very high value was noted, all the other benefit levels described in the literature clustered at the lower end of the range. We suggest a point estimate of $89, based on the findings from a well-designed study of the nonenergy benefits resulting from Public Service Company of Colorado's Energy $avings Partners Program (Magouirk 1995). That study measured the post-weatherization reduction in the *amount* of bad debt written off by participating households. In addition, the decrease in the *number* of accounts that were written off was measured. The two factors combined yielded the $89 NPV reported above. That number is near the high end of the range suggested by Skumatz and Dickerson (1999) for two California low-income programs but at the low end of the range suggested in an extensive study of the values of nonenergy benefits conducted for the state of California (TecMRKT Works et al. 2001).

Reduced Carrying Cost on Arrearages

Weatherization programs lower energy consumption for participating customers, thereby reducing the size of their energy bills and making it possible for them to pay a larger portion of those bills. This in turn reduces the amount of customers' bills that are in arrears. As these arrearages decline, the carrying costs borne by utilities (i.e., the interest on the amount in arrears) are also reduced.

According to the literature reviewed, the net present value of this benefit ranges from $4 to $110 (Table 2). As a point estimate, we chose $57, which is the midpoint of the savings calculated by Skumatz and Dickerson (1999) for two low-income programs in California. (PG&E's Low-Income Weatherization Program and its Venture Partners Pilot Program). The Skumatz and Dickerson study calculated savings based on likely program-induced reductions in arrearage balances, the magnitude of pre-weatherization arrearages in eligible households, and prevailing interest rates.

Fewer Notices and Customer Calls

As noted above, households that receive weatherization services tend to lower their energy consumption as a result, leading to lower energy bills, which are easier for them to pay. Consequently, utilities are required to send out fewer notices in response to late payments and will receive fewer customer calls regarding these situations. All of this results in a savings to utilities for staff time and materials.

As shown in Table 2, the NPV of this benefit reported in the literature ranges from $0 to $23. Our suggested point estimate is $6, which is at the high end of the range suggested by Skumatz and Dickerson (1999) but toward the lower end of the full range of benefits reported when other studies are included. The monetized benefits reported here represent a combination of the numbers calculated separately for late payment notices and for customer calls. An 18% reduction in the number of notices and calls was assumed, based on previous empirical findings on the incidence of reductions in the number of accounts written off for bad debt as a result of weatherization efforts (Magouirk 1995). This was multiplied by the annual cost per household of notices and customer calls to produce an estimate of savings per participant.

Fewer Shut-offs and Reconnections for Delinquency

As explained above, weatherized households are less likely to fall behind on their bill payments, meaning that they are less likely to have their utility service cut off for nonpayment. Because utilities incur costs to disconnect customers and to reconnect those households in the future, they experience a monetary savings as the result of customers being better able to pay their bills and retain service.

The net present value of this benefit ranges from $2 to $15 (Table 2). As a point estimate, we chose $8, which is the midpoint of the range of potential savings calculated by Skumatz and Dickerson (1999) for two PG&E low-income programs. This value is also very close to the benefits reported in several other studies of low-income weatherization efforts. The savings reported here were estimated based on the weatherization-induced reduction in the incidence of disconnections and the estimated costs of service shutoff and the portion of reconnection costs not covered by the customer.

Reduced Collection Costs

If fewer customer payments are delinquent, utilities spend less time and resources trying to collect what is owed them. However, it can be difficult to separate these reduced collection costs from the benefit associated with fewer late notices and customer calls, discussed above. A few of the reports reviewed for this study estimated collection costs *per incident* but did not put this in terms of the dollar value per all weatherized households. Because of the current lack of reliable estimates for this benefit, we will not attempt to assign it a monetary value.

2.2 SERVICE PROVISION BENEFITS

Fewer Emergency Gas Service Calls

As part of the home weatherization process, deteriorating or malfunctioning gas appliances can be serviced or replaced and new connectors can be installed. This proactive service reduces the subsequent need for utilities to make emergency service calls when appliances or connectors break or malfunction. By avoiding these emergency calls, utilities save staff time and resources, which constitutes a monetary benefit.

The literature reports that the NPV of this benefit ranges from $77 to $394. However, because this benefit can only occur where houses are fueled by natural gas, the reported values must be adjusted downward if they are to describe the nation as a whole. To reflect the fact that 50.9% of U.S. households are heated by natural gas (U.S. Energy Information Administration 2000), the numbers reported above were multiplied by 0.509, yielding an adjusted range of $39 to $201 for this benefit, as shown in Table 3. We suggest $101 as a reasonable point estimate. This number is at the midpoint of the range of values reported by Skumatz and Dickerson (1999) for two PG&E low-income programs and near the midpoint reported in the TecMRKT Works (2001) study (after their adjustment to reflect natural gas usage). The range of numbers reported in the Skumatz and Dickerson paper were calculated based on plausible ranges of service call costs and weatherization-induced reductions in the incidence of such calls (which dropped from 27% of households before weatherization to only 7% afterward, according to Magouirk, 1995).

Table 3. Ratepayer Benefits: Service Provision

Nonenergy Benefit	Range of Benefits (in 2001 $ per participating household: Net Present Value)	Point Estimate of Benefits (in 2001 $ per participating household: Net Present Value)
Fewer emergency gas service calls	39 - 201	101
T&D loss reduction	33-80	48
Insurance savings	0-2	1

Transmission and Distribution Loss Reduction

As a natural consequence of transporting electric power along transmission and distribution lines, a certain amount of energy is lost. These T&D losses are borne by the responsible utility and its customers. Because weatherization programs cause reductions in household electricity use, they likewise reduce the amount of electricity that must be transported and this results in a decrease in the T&D losses that occur. These savings often occur even in dwellings that are not electrically heated, because electricity usage for a number of purposes (e.g., furnace fans and pumps, air conditioning, lighting) can be affected by home weatherization measures.

The net present value of T&D loss reductions reported in the literature range from $33 to $88 (Table 3). Our suggested point estimate is $48, the midpoint of the possible benefit values reported by Skumatz and Dickerson (1999) for PG&E's Low Income Weatherization and Venture Partners Pilot Programs. The monetized value of the T&D losses reported here were calculated by multiplying the percentage of power that is typically lost through transmission and distribution (approximately 10%) by the avoided cost of power.

Insurance Savings

To the extent that the services performed by weatherization programs include the fixing of gas leaks and the repair or replacement of faulty appliances, the result is likely to be a reduction in the risk of household explosions and fires. This, in turn, would tend to lower the utility's insurance costs. Such cost savings are expected to occur whether the utility is self-insuring or buys coverage from another company.

The net present value of this benefit ranges from $0 to $2 (Table 3). As a point estimate, we chose $1, which is the midpoint of this range of potential savings values. The savings in insurance expenses reported here were estimated based on the magnitude of claims made in a typical year and the risk reduction associated with weatherization efforts. Skumatz and Dickerson (1999) assumed that the reduction in claims would fall by roughly the same factor that gas emergency calls would be reduced, as reported by Magouirk (1995).

3. BENEFITS TO HOUSEHOLDS

Low-income households that participate in weatherization programs are the recipients of two different types of nonenergy benefits. Point estimates of the average lifetime value of each are provided in Fig. 2. First, there are benefits that relate in some way to the affordability of low-income housing. These include: (1) water and sewer savings; (2) property value benefits; (3) avoided shut-offs and reconnections; (4) reduced mobility; and (5) reduced transaction costs. The other type of household benefit concerns the safety, health, and comfort of residents and has three components: (1) fewer fires; (2) fewer illnesses; and (3) improved comfort and related factors. Each of these household benefits is discussed in its own section, below.

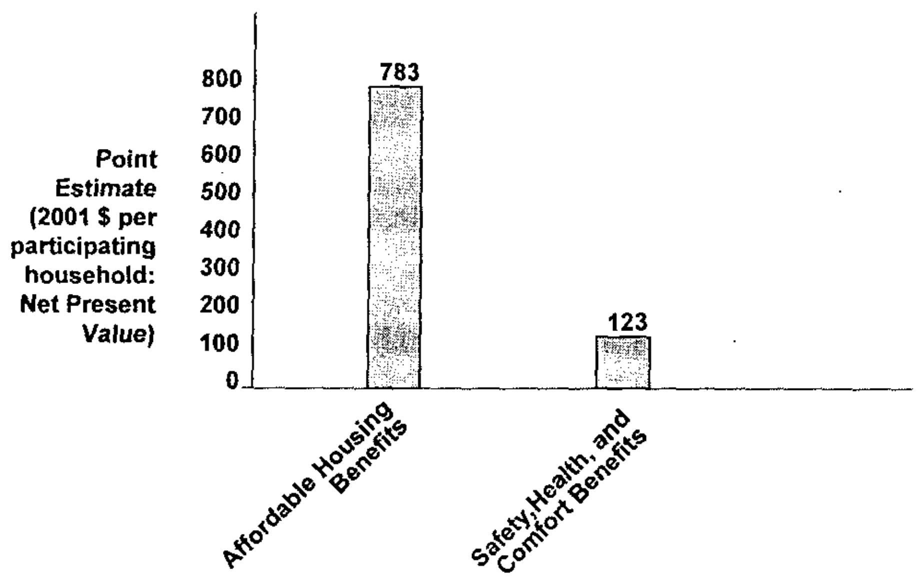

Fig. 2. Average Lifetime Monetary Value of Household Benefits, by Type

3.1 AFFORDABLE HOUSING BENEFITS

Water and Sewer Savings

Many of the homes serviced by a weatherization program receive low-flow showerhead and faucet aerator retrofits as part of the package of energy-efficiency measures installed. In addition to saving energy, these measures result in reduced household water use. Accordingly, households receiving these services save money on their water bills and, because sewer charges are generally based on the amount of water consumption, on their sewer bills as well.

A number of different estimates of the magnitude of water and sewer savings was presented in the literature reviewed for this study. Although most of those estimates were presented in terms of annual savings per household, they are presented here in terms of their net present value over the lifetime of the measures installed. The NPV of these savings ranges from $62 to $1607 (Table 4). Our best current estimate for this benefit is $271 but, as explained previously, there is substantial uncertainty associated with any point estimate made for the entire low-income Weatherization Assistance Program.

Table 4. Household Benefits: Affordable Housing

Nonenergy Benefit	Range of Benefits (in 2001 $ per participating household: Net Present Value)	Point Estimate of Benefits (in 2001 $ per participating household: Net Present Value)
Water and sewer savings	62-1607	271
Property value benefits†	0-5413	180
Avoided shut-offs and reconnections	0-52	17
Reduced mobility	0-1460	278
Reduced transaction costs	0-131	37

†occurs one time only in year weatherization is performed

The point estimate of $271 suggested above is based on information provided by Skumatz (2001) on average annual water savings per participating household resulting from the installation of faucet aerators and low-flow showerheads. This average household savings number was multiplied by the mean cost per gallon of water nationwide (U.S. Environmental Protection Agency 1997). The resulting number was updated to 2001 dollars using the multiplier suggested by the Consumer Price Index (Bureau of Labor Statistics 2001).

Property Value Benefits

In many cases, weatherization programs make some structural repairs and improvements to the houses they service in addition to installing energy efficiency measures. The structural improvements that are provided typically increase the property value of the homes receiving them. This represents a monetary benefit for the affected households that goes beyond the dollar savings associated with the energy efficiency improvements that are made. In addition, structural repairs can extend the useful lifetime of the affected dwellings and preserve the existing stock of affordable low-income housing.

According to the literature reviewed, the property value increase associated with home weatherization ranges from a minimum net present value of $0 to a maximum of $5413 (Table 4). Although one document (Riggert et al. 1999) suggests using the high value shown at the top of the range, all the other articles and reports reviewed for this study present values that cluster around the lower end of the scale. Those lower values are typically based on the assumption that the property value increase is equal to the cost of structural repairs made to the home in question. We suggest a point estimate of $180 for this benefit, based on the findings of the national weatherization evaluation (Brown et al. 1993). That study found that, in 1989, the average amount spent on materials for structural repairs nationally was $126. By adjusting that figure to 2001 dollars using the multiplier of 1.428 suggested by the Consumer Price Index (Bureau of Labor Statistics 2001), we get the $180 noted above.

Avoided Shut-offs and Reconnections

As explained in Chapter 2, weatherization programs result in decreased energy consumption for the homes serviced and this, in turn, means lower energy bills. Accordingly, weatherized households are less likely to fall behind on their bill payments and are less likely to have their utility service shut off for nonpayment. By avoiding service terminations, low-income customers experience a two-fold benefit. First, they get to retain the full use of their dwelling unit, the value of which is equivalent to the rent that would be "lost" if it were paid for a house (or portion of a house) that was unusable due to the lack of utility service. Also, the affected customers avoid having to pay a subsequent restart fee. While some authors include the perceived "value of service" experienced by the customer (i.e, how much it is worth to the customer to avoid a service disruption) as an additional benefit, this measure is not included here because of the difficulty of objectively assigning a dollar value to it.

The values for avoided shut-offs and reconnections presented in the literature range from $0 to $52 (Table 4). These numbers exclude the "value of service" benefit described in some studies, as noted above. A reasonable point estimate for this benefit is $17, which represents the upper end of the range given by Skumatz and Dickerson (1999) for lost rental value and cost to restart in their study of PG&E's Venture Partners Pilot Program. This value is considered reasonable to use here because a newer study (TecMRKT works et al. 2001) suggests a somewhat higher value for this benefit, putting the $17 figure roughly in the middle of the full range. Skumatz and Dickerson calculated lost rental value based on the likely reduction in termination rates and the assumed rent for a housing unit over a limited shut-off period. The cost to restart service was based on the projected reduction in termination rates and the restart costs per household, which include a reconnection fee and the value of lost work time.

Reduced Mobility

When household energy costs are high, less money is available for other purposes, including paying rent or making mortgage payments. This can be especially difficult for low-income households, where funds are very limited. In some cases, high energy costs can lead occupants to voluntarily move out of their current dwelling in favor of one with lower energy bills. In other instances, households with insufficient funds to cover all their expenses can be evicted for a failure to make housing payments or can be forced to move after utility service is discontinued. While the freedom to choose to be mobile is generally considered desirable, the mobility discussed here is associated with economic hardship and a lack of options. This kind of mobility, which is characterized by frequent and unwanted moves, can have the side effect of increasing school drop-out rates in the affected households. In turn, this can lead to a lifetime of lower earnings for those who prematurely terminate their education. By lowering household energy bills, weatherization programs can reduce mobility, thereby preventing some youth from dropping out of school and increasing their earning potential. That increase in earnings is a monetary benefit of weatherization that can be quantified.

The values for reduced mobility presented in the literature range from $0 to $1,460 (Table 4). Our suggested point estimate for this benefit is $278, which is the average of the point estimates presented by Skumatz (2001) for two different low-income weatherization programs. Skumatz calculated the value of reduced mobility based on: (1) the estimated effect of weatherization efforts on reducing the school drop-out rate; and (2) the estimated difference in lifetime earnings between high school graduates and drop-outs.

Reduced Transaction Costs

If they were not served by a weatherization program, some low-income households might choose to install certain energy-efficiency measures on their own. However, to do so, they would first have to become familiar with the needed retrofit measures and locate the necessary materials. The time and effort required for that represent a set of "transaction costs" for low-income households, and avoiding those transaction costs amounts to a benefit for those receiving weatherization services. By assigning a monetary value (approximating minimum wage) to the time saved by participants, the magnitude of transaction costs can be identified.

As shown in Table 4, the net present value of reduced transaction costs reported in the literature range from $0 to $131. Our suggested point estimate is $37, the midpoint of the possible benefit values reported by Skumatz and Dickerson (1999) for PG&E's Low Income Weatherization and Venture Partners Pilot Programs. The reduced transaction costs reported here were calculated based on the number of compact fluorescent lamps installed per household under the programs studied and the estimated reduced transaction costs per bulb. That monetized benefit was then doubled to reflect the fact that weatherization programs include many more measures than compact fluorescent bulbs alone. The resulting value seems conservative in light of the fact that home weatherization involves the installation of a number of different products (e.g., insulation, sealants, low-flow showerheads, storm windows, programmable thermostats) which consumers would have to locate and learn about if they were to perform the work themselves.

3.2 SAFETY, HEALTH, AND COMFORT BENEFITS

Fewer Fires

Many low-income homes have old and poorly-maintained space and water heating systems. These present a risk of fire resulting from gas leaks. Also, low-income households sometimes use dangerous supplemental heat sources like gas grills or electric space heaters, and this is especially problematic in those instances where the primary heating source is disconnected due to nonpayment. Weatherization programs can improve the operation of space and water heating systems and reduce the need for supplemental heating. As a result, fewer fires occur in weatherized homes, and this represents a real benefit to the affected households.

The net present value of fewer fires reported in the literature ranges from $0 to $555 (Table 5). We suggest using $68 as a point estimate for this benefit. This value of fewer fires over the lifetime of the weatherization measures installed is based on the annual per household value for this benefit presented by Brown et al. (1993) in the national weatherization evaluation, adjusted to 2001 dollars using the multiplier suggested by the Consumer Price Index (Bureau of Labor Statistics 2001). The study by Brown et al. estimated the number of fires prevented by the national Weatherization Assistance Program, using national statistics on the occurrence of fires and fire death rates, and attributed a value to the associated property damage and deaths based on residential fire-loss statistics and the projected value of future lifetime earnings.

Table 5. Household Benefits: Safety, Health, and Comfort

Nonenergy Benefit	Range of Benefits (in 2001 $ per participating household: Net Present Value)	Point Estimate of Benefits (in 2001 $ per participating household: Net Present Value)
Fewer fires	0-555	68
Fewer illnesses	0-2191	55
Improved comfort and related factors	Not Available	Not Available

Fewer Illnesses

Some authors have suggested that people living in houses with sufficient and continuous heat during the colder months of the year are likely to get fewer colds. When adults get fewer colds, it means that they experience fewer lost days of work and the accompanying loss of wages. In addition, when children are sick, a parent or guardian often has to miss work to care for them, again at the cost of lost wages. Accordingly, weatherization improvements that result in warmer and less drafty homes could lead to fewer illnesses and the monetary benefits that go along with that. It should be noted that tightening up homes could lead to increases in indoor air pollution and associated illnesses. However, properly conducted energy audits allow for adequate air changes in the home to minimize this risk.

The net present values reported in the literature for fewer illnesses range from a low of $0 to a high of $2191. We suggest a point estimate of $55. This value was calculated using the method described in Skumatz (2001). Skumatz developed a point estimate for the benefit of fewer illnesses associated with low-income weatherization efforts, based on survey findings regarding the number of lost workdays avoided and an assumed average wage earned by the affected workers.

Improved Comfort and Related Factors

Because houses tend to become warmer and less drafty after they are weatherized, their occupants are likely to experience increased comfort levels. In addition, the improvements made to homes during the weatherization process often make them less noisy and can improve their appearance. All of these represent benefits that are real but are very difficult to measure objectively. Some innovative work has been performed in this area, most notably in the form of survey research that asks respondents to characterize the value of various nonenergy benefits relative to the energy savings that they have received as a result of program participation (Skumatz et al. 2000). However, it is not clear whether the values calculated by such approaches, which assign a dollar value to a given benefit based on its perceived importance to the recipient, are either valid or reliable given the very hypothetical nature of the task set to the respondents. Accordingly, we will not attempt to assign a dollar value to comfort, noise, and aesthetic benefits at this time.

Improved indoor air quality is another benefit associated with weatherization programs. Faulty furnaces can release carbon monoxide into houses, with very negative health effects. Improvements to heating equipment made during the weatherization process can prevent such releases, and the installation of carbon monoxide monitors can alert household occupants to the presence of this dangerous gas. Despite its importance, we will not attempt to assign a monetary value to the benefit of improved indoor air quality because of the current lack of reliable estimates.

Weatherization providers are required to give a booklet on the hazards of lead-based paint (U.S. Environmental Protection Agency 2001) to households in which such paint could be present. This booklet presents information on the dangers of lead poisoning and how they can be reduced or eliminated. Because lead can have very adverse impacts on those exposed to it–especially children–educational efforts like the one described above can have the positive effect of protecting the health of household residents. Due to a lack of information on the monetary value of this benefit, we do not attempt to quantify its worth.

4.0 SOCIETAL BENEFITS

Following the literature, the *societal* nonenergy benefits attributable to weatherizing low income homes are broken into three categories: environmental, social and economic. Fig. 3 gives point estimates of the average lifetime monetary value associated with each of the three benefit types. The findings distilled from the literature are reported in sub-sections 4.1, 4.2, and 4.3, respectively.

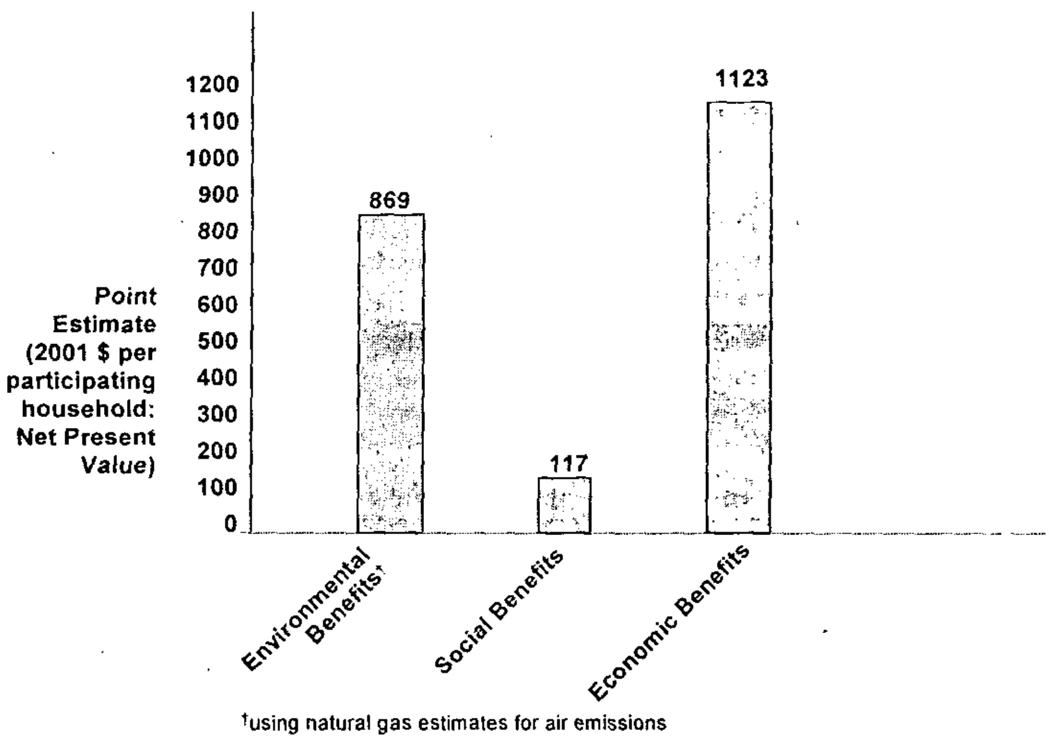

Fig. 3. Average Lifetime Monetary Value of Societal Benefits, by Type

4.1 ENVIRONMENTAL BENEFITS

Environmental benefits pertain to how the environment can be improved by weatherizing low income homes. The most frequently studied environmental benefits arise from the reduction of air pollutants due to the reduction in the burning of fossil fuels, either in the home (e.g., natural gas) or at central power stations to produce electricity. Other categories of environmental benefits quantified in the literature include less impingements upon fish around power plant water sources, and reduced water use and, subsequently, less sewage. Table 6 provides ranges and point estimates for these environmental benefits.

Table 6. Environmental Benefits

Nonenergy Benefit	Range of Benefits (in 2001 $ per participating household: Net Present Value)	Point Estimate of Benefits (in 2001 $ per participating household: Net Present Value)
Air Emissions - Natural Gas		
Carbon (CO_2)	40 - 32,189	102
Sulfur Oxides (SO_x)	.02 - 6015	23
Nitrogen Oxides (NO_x)	.02 - 2254	48
Carbon Monoxide (CO)	.21 - 758	46
Methane (CH_4)	.07 - 269	92
Particulate Matter (PM)	.01 - 6983	9
Subtotal	40 - 49,176	320
Air Emissions - Electricity		
Carbon (CO_2)	167 - 97,857	305
Sulfur Oxides (SO_x)	31 - 40,872	92
Nitrogen Oxides (NO_x)	11 - 17,290	523
Carbon Monoxide (CO)	36 - 81	39
Methane (CH_4)	.68 - 1.15	.91
Particulate Matter (PM)	.27 - 704	14
Subtotal	246 - 156,805	974
Other Benefits		
Heavy Metals (air emissions)	1.39 - 17,205	380
Fish Impingement	23.44 - 23.44	23.44
Waste Water and Sewage	3.36 - 657	146
Subtotal	28 - 17,885	549
Total†	68 - 67,061	869

† uses natural gas estimates for air emissions

With respect to air emissions, the literature contains a wide range of estimates for several factors that are needed to estimate benefits. These factors include (1) the number of pounds of pollutants emitted per unit of energy service delivered (e.g., lbs/ mmbtu), (2) average energy savings per weatherized home, (3) reductions in pounds of pollutants emitted per weatherization, and (4) value in dollars associated with reducing units of air pollutants (e.g., $/ton of carbon dioxide emissions reduced). The approach followed to estimate the range of benefits was to take the lowest (highest) value for each factor to calculate the lower (upper) bound. The approach taken to develop a point estimate varied by each type of air emission. In general, mid-range and frequently mentioned estimates were used. Sources used for the environmental benefit review include: Brown et al. (1993), Berry (1997), Skumatz and Dickerson (1997, 1999), Skumatz (2000), Riggert et al. (1999), Riggert et al. (2000), Hill et al. (1999), Burtraw et al. (1997), Burtraw and Toman (1997), TecMRKT Works et al. (2001), Biewald et al. (1995), and National Research Council (2001).

The ranges in benefits associated with reducing air emissions are large and arise due to a host of methodological issues. Two key problems are related to choice of benefit estimation method and where studies had been conducted. The former problem is particularly acute with respect to valuing emission reductions. Generally, one of two methodological approaches is taken. One approach is to value emission reductions equal to the value of emission permits that are being traded in an emissions market (or the expected value for such permits if the market does not yet exist). This value approximates the cost faced by emitters for complying with emission reduction regulations. These values are attractive for benefit estimation exercises because they can be documented, if the market exists, or closely estimated, if the market does not yet exist.

The market valuation method tends to yield lower values for emission reductions than the second method, which calls for a comprehensive estimation of the benefits associated with emission reductions. In other words, a drawback to using the market values of emissions permits is that these values do not directly encompass important benefits accruable to society from the emissions reductions. For example, the market values do not reflect improvements to human health and ecosystems or decreasing rates of deterioration of the exterior of buildings and other materials exposed to the pollutants. Estimating all these benefits can lead to dramatically higher values for reducing harmful emissions to the air. The large ranges in benefits shown in Table 6 are mostly attributable to studies that adopted one or the other of the two methodologies. It must be noted that adopting a comprehensive benefits estimation methodology also increases the uncertainty in the valuation process because estimating health and ecosystem benefits is extraordinarily difficult. Because each method has significant strengths and weakness, neither has been universally accepted and wide ranges of benefits estimation can be expected to continue into the foreseeable future. In this study, we tended to favor the market valuation approach when generating point estimates of environmental benefits.

Where studies have been done is a second source of variation in the numbers presented in Table 6. This is because spatial factors can greatly impact the reductions in emissions per weatherized home. It is well known that the number of heating degree days, which vary across the country, is tightly correlated with energy savings and, ultimately, with air emission reductions due to weatherization. Thus, findings by studies done in California will be different from studies done in Vermont; both may not be generalizable to the entire country but a value somewhere in the range probably is. Cooling degree days also vary by climate zone but these savings are usually not included in energy savings estimates, and, conversely, not in air emission reduction estimates.

Fuel used for heating also varies across the country. Studies conducted in areas dominated by natural gas are different than studies done in areas more reliant on electricity. What types of fuels are used to generate electricity are also important, as coal types vary considerably and coal is considerably different from natural gas, for example. Generally, emission reduction estimates do not encompass homes that use multiple fuels for heating (e.g., electricity and wood are common in the Pacific Northwest). Impacts upon other energy end uses, such as air conditioning, are also not incorporated in these analyses. Studies done in limited market areas with unique fuel mixes and climate yield large ranges in results and this is also indicated in the ranges exhibited in Table 6.

It should also be noted that the environmental benefits listed in Table 6 are not comprehensive. Categories of environmental benefits not apparently quantified in the literature include reductions in water pollution (e.g., from run-offs from power plant sites, leaching of toxics into the groundwater from mining operations), land use changes (e.g., associated with extraction of natural resources), and solid waste (e.g., fly-ash from electric generation plants). The literature also does not include complete life cycle assessments that would encompass all pollutants associated with each phase of a home heating fuel (i.e., from extraction of raw materials to materials processing to consumption of the fuel to waste disposal issues) to allow comparison with the environmental implications associated with materials used to weatherize homes (e.g., assessing the life cycle emissions -- extraction, processing, manufacturing, transportation, use, and end-of-life disposal of insulation). For example, not included in this analysis are environmental costs associated with the production of fiber glass insulation, epoxy-based window caulking, double-pane windows, and other measures commonly installed in weatherized homes.

4.2 SOCIAL BENEFITS

Social benefits represent a catch-all category of benefits attributable to weatherization that are clearly not environmental or economic. In this sub-section we will focus on one such benefit that is discussed in the literature and for which the effects have been monetized: avoided unemployment benefits. This refers to the employment of people in the course of weatherizing homes who would have been unemployed otherwise. Sources for these benefits include Brown et al. (1993), Skumatz and Dickerson (1999), and Riggert et al. (1999). Other social benefits which have not been monetized include: social equity (Berry et al. 1997, National Consumer Law Center 1999), and improvement in community pride through improvement in the local housing stock.

The range for avoided unemployment benefits (Table 7) was developed by using the low and high estimates found in the literature. To establish a point estimate, the value reported by Brown et al. (1993) was adjusted to 2001 dollars based on the Consumer Price Index (Bureau of Labor Statistics 2001). Factors that impact the reliability of estimated benefits include the availability of jobs in various areas of the country and over time. In areas having numerous job opportunities, it is harder to argue that there are avoided unemployment benefits. However, since low income weatherizations are often conducted in economically distressed communities that typically do not benefit from national or even regional upturns in the economy, it can be more strongly argued that avoided unemployment benefits are valid.

Table 7. Social Benefits

Nonenergy Benefit	Range of Benefits (in 2001 $ per participating household: Net Present Value)	Point Estimate of Benefits (in 2001 $ per participating household: Net Present Value)
Avoided Unemployment Benefits†	0 - 183	117

† occurs one time only in year weatherization is performed

4.3 ECONOMIC BENEFITS

Weatherizing low income homes can yield a variety of economic benefits. One group of benefits is related to spending money on weatherization. These expenditures can directly result in new jobs and increases in personal income which can translate into increases in federal income tax collections. Additionally, weatherization expenditures can impact the local economy as a portion of every dollar prevented from leaving the community to import energy is spent within the community. This is known as the multiplier effect. Most studies only focus on the impacts within economically distressed areas and do not address the broader economy, where jobs and incomes may be lost, for example in energy production and distribution operations. Given the scale and scope of the energy production and distribution industries and the fact that energy consumption has continued to increase over time, it is highly unlikely that any job losses in those industries can be attributed to weatherization activities.

Of course, saving energy has national security implications, too, by reducing the need for energy imports. Lastly, it has been hypothesized that owners of rental units may benefit from the weatherization of rental units if the low income households save enough money on energy bills to better be able to pay their monthly rents.

Table 8 contains ranges and estimates for the economic-related factors listed above. Sources for these estimates include the Weatherization Network (1999), Nevin et al. (1998), Brown et al. (1993), TecMRKT Works et al. (2001), Riggert et al. (1999), Skumatz and

Dickerson (1997), Skumatz (2001 and 1998), Berry et al. (1997), Hill et al. (1998), RPM Systems (1995), Galvin (1999), National Research Council (2001), and Office of Transportation Technology (2001). Table 8 indicates that the direct and indirect economic benefits of low income weatherization programs can be quite significant.

Table 8. Economic Benefits

Nonenergy Benefit	Range of Benefits (in 2001 $ per participating household: Net Present Value)	Point Estimate of Benefits (in 2001 $ per participating household: Net Present Value)
Direct and Indirect Employment†	115 - 4354	801
Lost Rental	0 - 2.19	1.14
National Security	75 - 3286	321
Total	190 - 7642	1123

†occurs one time only in year weatherization is performed

Numerous factors impact the validity of the estimates contained in Table 8. As discussed above, the availability of jobs in an area impacts the job creation and increased federal benefits. The degree to which a local economy is sheltered from needing to import goods and services will impact the local multiplier effect, and housing availability will impact the lost rental benefit.

5. SUMMARY AND CONCLUSIONS

Table 9 summarizes the results of the literature review presented in the preceding three chapters. Overall, societal benefits are estimated to be substantially larger than ratepayer and household benefits. *Ranges* for the societal benefits are also much greater than for the other two categories of nonenergy benefits. The total point estimate for nonenergy benefits in all categories associated with weatherizing a home is $3346, in 2001 dollars. As explained in Chapter 1, this represents a national average figure which, like any point estimate, has substantial uncertainty

Table 9. Summary of Benefits for Each Major Category and Subcategory

Nonenergy Benefit Category/Subcategory	Range of Benefits (in 2001 $ per participating household: Net Present Value)	Point Estimate of Benefits (in 2001 $ per participating household: Net Present Value)
Ratepayer Benefits		
Payment-Related Benefits	27-3680	181
Service Provision Benefits	72-283	150
Total for this Category	99-3963	331
Household Benefits		
Affordable Housing Benefits	62-8663	783
Safety, Health, and Comfort Benefits	0-2746	123
Total for this Category	62-11,409	906
Societal Benefits		
Environmental Benefits	68-67,061	869
Social Benefits	0-183	117
Economic Benefits	190-7642	1123
Total for this Category	258-74,886	2109
Total for All Benefit Categories	419-90,258	3346

associated with it. Actual benefits will be higher or lower in specific households and locales based on what programs exist, what fuels are used, the magnitude of energy savings, and other factors. More important than the precise dollar figures is the indisputable fact that nonenergy benefits represent a significant addition to the energy savings benefit achieved by the Weatherization Assistance Program.

The point estimate for total nonenergy benefits given above is substantially higher than the total value presented a decade ago in ORNL's national weatherization evaluation (Brown et al. 1993). The magnitude of all nonenergy benefits discussed in that study, when adjusted for inflation, is $1394 in 2001 dollars. The difference between that figure and the $3346 reported in this document is due almost entirely to the fact that our study quantified a much broader array of nonenergy benefits than was addressed in the earlier work. For instance, the only ratepayer benefit discussed in the national evaluation was the reduced carrying cost on arrearages. In contrast, our treatment of this topic also included avoided rate subsidies, lower bad debt write-off, fewer emergency gas service calls, transmission and distribution loss reduction, and several other factors. Similarly, our examination of household benefits included a number of factors—such as water and sewer savings, reduced mobility, and fewer illnesses—that were not considered in the earlier work. In the realm of societal benefits, our values are very similar to those presented in the earlier study for both social and economic factors. For environmental benefits, the values reported in this document are substantially higher than those presented in the earlier report but, once again, this is largely due to our treatment of additional factors. While Brown et al. only assessed the benefits of reductions in two types of air emissions, sulfur dioxide (SO_2) and NO_x, our study looked at a variety of other air emissions (e.g., CO_2, CO, CH_4) plus other environmental factors such as heavy metals and fish impingement. An additional explanation for the difference between the value of environmental benefits reported in the two documents is that our study was based on an updated, and substantially higher, amount of average household energy savings, which directly affects the magnitude of emissions reductions. In all nonenergy benefit categories, where our report dealt with the same specific benefits addressed by Brown et al., our values tended to be very similar.

The combined net present value of $3346 for all nonenergy benefit categories compares to an average net present value of energy savings of $3174 and an average total cost per weatherization of $1779, once again in 2001 dollars. The energy savings figure is based on the value of savings for houses heated by natural gas taken from a meta-evaluation of the Weatherization Assistance Program performed by ORNL (Berry et al. 1997) to update findings from the national evaluation. The value of annual energy savings reported in that study was inflated to account for future energy prices using long-term projections developed by the U.S. Energy Information Administration (2001) and discounted using the discount rate recommended by the Office of Management and Budget. The figure used here for weatherization costs represents *total* costs (including labor and materials as well as program overhead and management) for the average weatherized dwelling and was generated by taking the most recent available information from the Weatherization Assistance Program's grants management data system and adjusting the average cost per weatherized unit to 2001 dollars using the Consumer Price Index multiplier.

It is important to note that total estimated nonenergy benefits are slightly greater than the value of energy savings over the lifetime of the weatherization measures installed. The benefit/cost ratio for gas-heated houses, combining both energy and nonenergy benefits and comparing that figure to total costs (labor, materials, and overhead) for the average weatherized home, is approximately 3.7, meaning that $3.70 in benefits are realized for every dollar spent. This comparison of *all* benefits to *all* costs is referred to as the "societal perspective." Low and high values for the societal benefit/cost ratio, using low and high nonenergy benefit estimates, are 2.0 and 52.5, respectively.

Whatever assumptions are made, the total estimated value for all nonenergy benefit categories combined is lower than it could be, because the estimate does not contain some benefits that have not been monetized. It must also be noted that there are numerous uncertainties in the estimates reported above. The environmental benefit calculations in particular are subject to wide ranges in assumptions about air emissions prevented per weatherized home and the dollar values associated with reducing each air pollutant. In addition, nonenergy benefits in many different categories are likely to vary widely by climate, fuel type, and local economic conditions. In general, our point estimates are conservative and tend to be much closer to the lower than the upper end of the full range of values presented in the literature.

Potentially important future research projects on the subject of nonenergy benefits include the following: assessing subjective nonenergy benefits that participants receive from weatherization (e.g., improved comfort); following a panel of weatherized homes over time to assess the benefits of weatherization provided to successive occupants; and conducting comprehensive life cycle assessments to better understand all the environmental benefits and costs associated with energy use reductions and installation of energy efficiency measures.

6. ACKNOWLEDGMENTS

We wish to acknowledge two major sources for this literature review. The first source is the compendium of high quality work performed in this area over the last several years by Lisa Skumatz and several of her collaborators. The second extremely helpful source is the meta-study conducted by Jeff Riggert and his colleagues in 1999. In addition, we would like to thank Linda Berry and Joel Eisenberg for providing help and encouragement throughout the course of this project and for their valuable comments on this report.

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